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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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VOL. CVII.—No. 2781.] *LONDON: FRIDAY, APRIL 18, 1919.* [*Registered at the General Post Office as a Newspaper.*] PRICE 9d. BY ISLAND POST ... 11d.

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See Advertisement, page 23, last week.
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AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

John H. Wilson & Co., Ltd.
Birkenhead.
See Illustrated Advertisement Page 9.

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Always British Large Sizes.
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For Illustrated Advertisement, see page 6. 7356

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Manufactured by 3591
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7182
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GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 7364
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TUBES, LIMITED, BIRMINGHAM. 3179

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Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3591
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See page 110, April 11. 7263

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Specification and Workmanship equal to Main Line Locomotives.
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FROM 50 TO 600 YARDS PER HOUR.
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6363
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See displayed advertisement every alternate week.
JOHN M. HENDERSON & CO., ABERDEEN.

"Spencer-Hopwood" Patent Boilers.
Sole Makers:
W. H. SPENCER & CO., HITCHIN, HERTS.
See page 18, April 11. 7454

Henry Wells Oil Co.,
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WORKS: SALFORD, MANCHESTER. 7184

Iron and Steel
Tubes and Fittings.
6020
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 99.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, } Row's PATENTS.
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SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
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IRON AND STEEL.
Stewarts and Lloyd's, Ltd.,
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WINCHESTER HOUSE, OLD BROAD STREET, E.C.
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LIVERPOOL WAREHOUSE—53, PARADISE ST.
MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—139, BUTE ST.
BIRMINGHAM WAREHOUSES—NILE STREET, SHEEPSCOTE STREET, and 10, COLESHILL STREET.
See Advertisement page 28. 7308

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FLEXIBLE, NON-RUSTING
Metallic Hose-Covering to protect & strengthen tubing for all pressures and purposes. As supplied for H.M. Govt.—AERATORS LTD., Edmonton, London, N. 18.

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ENGINEERING, IRON AND STEEL WORKS
Valuers.
CONSULTING ENGINEERS, REFEREES, AND ARBITRATORS.
Established over 50 years. 7108
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Locomotive Traversers
(ELECTRIC).
7182
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See Illus. Advt. last week, page 15. 7046

See's Patent **Ash Ejector.**
Hydro-Pneumatic
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

Separators
— FOR —
EXHAUST STEAM TURBINES COMPRESSED AIR, &c.
STEAM DRYERS, METALLIC PACKINGS.
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New Chicago Automatics.
Three Sizes, Delivery from Stock.
NEW CAPSTANS, 1¼ in. through the wire feed.
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Augustin-Normand
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Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

Yarrow Patent
Water-Tube Boilers. 6594
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YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

John Bellamy Limited,
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GENERAL CONSTRUCTIONAL ENGINEERS. 1316
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STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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Hurst, Nelson & Co., Ltd.
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Head, Wrightson & Co.,
LIMITED.
See Advertisement page 58, April 11. 3402

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, **Dumbarton.** 6839
See Full Page Advt., page 78, April 4.

Taylor & Challen
Presses.
6165
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement, April 4.

Steel Castings.
THOMAS SUMMERSON & SONS, LTD., DARLINGTON. 6974

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S. H. HEYWOOD & CO., LTD., REDDISH. 7182

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MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION.
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Aluminium

INGOTS	for	JIGS & PULLEYS,
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WIRE	for	ELECTRIC CABLES,
SECTIONS	for	MOTOR BODYWORK,
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POWDER	for	PAINT, &c., &c.

1369
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THE BRITISH ALUMINIUM CO., LTD., 109, Queen Victoria St., London, E.C. 4.

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Steam Hammers,
Power Hammers,
Drop Stamps,
Band Saws. 7236
QUICK DELIVERY. LARGE STOCK.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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and all Engineering Exams. Correspondence coaching by practical engineers. I.C.E. successes 265 out of 303. Two Bayliss Prizes. "Proxime Accessit." Special features for foreign candidates. Write for booklet, &c.—Address, 7434, Offices of ENGINEERING.

A.M.I.C.E. and A.M.I.M.E.

Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 354, Oxford Road, Manchester.

Crystal Palace School of PRACTICAL ENGINEERING.

PRINCIPAL:—
J. W. WILSON, M.I.C.E., M.INST. MECH. E.

The New Course will Commence on April 30th. New Students enter at the school on the morning of April 29th. Prospectus, etc., of the PRINCIPAL. U 233.

GLAMORGAN COUNTY COUNCIL.

SUMMER MINING AND ENGINEERING SCHOOL, 1919.

SOUTH WALES COALFIELD.

This Summer School will be

held from AUGUST 4th to 23rd, at The UNIVERSITY COLLEGE, CARDIFF, and Courses will be provided as follows:—
Mining Engineering, Mechanical and Electrical Engineering and a Special Science Course for Teachers (Chemistry, Physics and Geology). The work in each course will be mainly practical.
A Surveying Course to meet the requirements of all grades of students will be held. Outdoor and Field Work.
Suitable "INTENSIVE and REFRESHER" Courses in all subjects for Demobilised Officers and other ranks will also be held.
Full particulars, prospectus and forms of application may be obtained on receipt of a stamped addressed foolscap envelope from the
CHIEF EDUCATION OFFICIAL,
Glamorgan County Hall, Cardiff. U 229

TENDERS.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, NATIONAL CARTRIDGE CASE FACTORY, BIRTLEY, CO. DURHAM.

For Sale by Tender, this FREEHOLD FACTORY.

The following is a brief description:—
SITUATION.—One-third mile from Birtley (N.E.R.) goods and passenger stations.
LAND.—Area 9 a. 1 r. 16 p. (about).
BUILDINGS.—Erected by the Government since the outbreak of the war and comprise:—Press, Machine and Casting Shops, Rolling Mills, &c. Constructed of brick and steel, with steel roof trusses and stanchions, covered with corrugated iron and floors of concrete, planking on concrete, steel plates and sales.
Offices, Transformer House, Canteen, Lavatories, &c., are built in brick with timber roofs covered with asbestos, slates, felt, &c.
Ground area of Buildings 189,310 ft. super (about).
POWER AND LIGHT.—Electric.
HEATING.—Sturtevants' Hot Air System, steam pipes and radiators, slow combustion stoves and open fires.
WATER.—From Public Main.
SIDINGS.—Total length on site 2870 ft.
Tenders will be received up to Noon on 10th May, 1919.
The Form of Tender showing the way in which offers can be made may be obtained from the DISPOSAL BOARD, Lands and Factories Section, Charing Cross Buildings, Embankment, London, W.C. 2. U 120

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

For Sale by Public Tender.

THE RUST-PROOFING PLANT
AT
NEW NORTH STREET, THEOBALDS ROAD.

The plant comprises:—
One Electrolytic CLEANING PLANT with Shunt-Wound Dynamo—600 amps. at 10 volts. Switchboard, Electrolytic Bath and sundry hot and cold tanks; by Canning & Co., Birmingham.
One 1 h.p. open type MOTOR and STARTER 440 volts d.c. by Mawdsley.
One Regenerative OVEN FURNACE by Wright & Co., Birmingham.
One Reavell AXIAL COMPRESSOR, type R, 25.
One 150 light GAS METER by Glover.
Two OIL TANKS.
One CONVEYOR, etc.
Tenders are invited for the purchase as a whole or in part.
Applications for permission to view and Tender Forms to be made to the CONTROLLER, Machinery and Plant (D) Section, Charing Cross Embankment Buildings, London, W.C. 2. U 209

RICHMOND MAIN SEWERAGE BOARD.

CONTRACT FOR STORES.

The Board are prepared to receive

Tenders for the Supply and

DELIVERY to their Works during the year ending May 31st, 1920, of the following STORES:—
Steam Coal.
House Coal.
Coke.
Grey Lime.
Buxton Lime.
Sewage Precipitants.
Jute Press Cloth.
Specifications and particulars may be inspected from 10 a.m. to 4 p.m. at the Office of Mr. WILLIAM FAIRLEY, M. Inst. C.E., Engineer to the Board, West Hall Road, Kew Gardens, where also Forms of Tender may be obtained.
Sealed Tenders, on the forms provided, to be delivered to the undersigned on or before Tuesday, May 13th, 1919.
The Board do not bind themselves to accept the lowest or any tender.
J. LESLIE G. POWELL,
Clerk to the Board.
The Sessions House,
Richmond, Surrey,
9th April, 1919. U 205

G. R.

BY ORDER OF THE DISPOSAL BOARD.

NATIONAL RIFLE FACTORY (No. 2).
GARRISON LANE, BIRMINGHAM.

For Sale by Tender, in one lot,

FREEHOLD, as built, and fitted with Electric Lifts, Lighting and Heating Plant, Main Shafting and Pulleys, and Motors operating the same.
Fronting on Garrison Lane, and Artillery Street, Trams pass the Factory. Adjoining Midland Railway and Birmingham and Warwick Canal.
Area of Land—3 a. 0 r. 10 p. (about).
Buildings—Cover 44,000 feet super (about).
Main Factory (One Floor) brick walls with steel framed glass and ruberoid roof. Offices (Three Floors) and Canteen (Two Floors) brick built with part asphalt and ruberoid roofs.
Electric Light and Power from Corporation Mains. Low pressure hot water heating.
For further particulars, permits to view, and Tender Forms, apply to
DISPOSAL BOARD, Lands & Factories Section, Charing Cross Buildings, Embankment, London, W.C. 2. T 997

April 7th, 1919.

Sale by Private Tender.

COMPLETE ALTERNATING CURRENT GENERATING PLANT consisting of:—
One 525 B.HP., and two 300 HP. Carrels three-cylinder Diesel Oil Engines with Reavell Compressors, direct-coupled to
Two 218 K.W. and one 325 K.W. Dick Kerr 2-phase 2000 volt.
50 period Alternators with direct-coupled Exciters.
Complete Auxiliary Gear, consisting of Reavell 4-stage Compressor, driven by direct-coupled 2000 volt, 2-phase, 100 HP. Induction Motor, Marble Switchboard with mechanical remote control for three generator and two feeder panels with the usual measuring and sychronising gear. Motor-driven, water circulating and fuel oil pumps, Heenan & Froude Water Cooling Plant for 7000 gallons per hour. Cooling Water and Fuel Oil Tanks, Fuel Oil Storage Tanks of 90 tons capacity and quantity of new and second-hand Spare Parts.
Also One 20 ton Engine Room Crane, 47 ft. span, with hand traverse, and electric hoist; and One 15 ton ditto, hand traverse, hoist 37 ft. 6 in. span.
The whole is in good running order, and adjusted to run on either tar or crude oil.
The plant may be inspected by prospective purchasers by appointment.
Offers will be considered for the whole or part of above plant.—Address, U 32, Offices of ENGINEERING.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.
NATIONAL PROJECTILE FACTORY, BIRTLEY, Co. DURHAM.

For Sale by Tender, this FREEHOLD FACTORY, with or without Machinery and Plant.

The following is a brief description:—
SITUATION.—¼ mile from Birtley (N.E.R.) Goods and Passenger Stations.
ROADS.—Two Macadam roads with foot-paths.
LAND.—Purchased by the Government—Area 53 a. 3 r. 14 p. (about).
BUILDINGS.—Erected by the Government since the outbreak of War. They consist of two main steel-framed buildings with corrugated iron sides and steel roof trusses boarded and covered "poilite" slates. Large Bond Store of similar construction but with galvanised and glazed roof; Main Store, Hydraulic Power Station, Stamping Shop, Loco. Shed, Carpenters' Shop, Offices, Latrines, Mess Room, Hospital, Garage and Petrol Store, Oil Store, etc., etc. Ground area of Buildings 541,602 sq. ft. (about).
POWER.—Electric, Hydraulic and Producer Gas Plant.
SIDINGS.—Over 40 sidings with a total length of 27,458 ft., four loading platforms.
HEATING.—Sturtevant Radiators and slow Combustion Stoves.
PLANT AND MACHINERY.—Comprising about 1,000 Lathes, Milling, Grinding, Planing, Shaping, Screwing and Drilling Machines, etc., Heating appliances and Canteen equipment; Hydraulic plant including 24 presses; Three Locomotives, 74 Railway Wagons, Three Steam Travelling Cranes, 43 Overhead Electrical Cranes, Electric Driving Plant including 142 Electric Motors, Lancashire and other Boilers, Shafting, Pulleys, etc., and very large assortment of miscellaneous plant.
Tenders will be received up to noon on 10TH MAY, 1919.
The form of Tender showing the way in which offers can be made, and Schedule of Machinery and Plant, may be obtained from the DISPOSAL BOARD, Lands and Factories Section, Charing Cross Buildings, Embankment, London, W.C.2. U 121

The Admiralty has for

DISPOSAL about 90 tons of Old 4-inch BRASS CONDENSER TUBES, lying at H.M. Dockyards, Portsmouth, Chatham, Devonport and Pembroke Dock. Tender Forms, due for return by the 30th April, may be obtained on application to the DIRECTOR OF CONTRACTS (Sales Branch), Admiralty, Whitehall, S.W. 1, quoting Schedule 36. U 248

G. R.

SALE BY TENDER.
BY DIRECTION OF THE DISPOSAL BOARD.

Tenders are Invited for the

following Steel Work:—
One Steel framed SKELETON SHED, total dimensions 180 ft. by 80 ft., with built up stanchions, horizontal rails, bracings, roof trusses and purlins.
This shed is lying at Messrs. Braithwaite & Co.'s Works, West Bromwich, Birmingham.
Full particulars, Tender Forms and Permits to view may be obtained from the Controller, Huts and Building Material Section, Disposal Board, Artillery Mansions, Victoria Street, S.W. 1.
Telegraphic Address: "Hutments," Victoria.
Telephone: Victoria, 1261. U 278

MANCHESTER SHIP CANAL.
CONTRACT No. 182.

The Directors of the Manchester Ship Canal Company are prepared to receive

Tenders for the Construction

of an OIL DOCK on the Northerly side of the Manchester Ship Canal, in the Urban District of Ellesmere Port and Whitby.
The Drawings may be inspected and copies of the Specification and Bill of Quantities obtained on and after 23rd April, 1919, at the Office of the Chief Engineer (Mr. H. A. REED, M.Inst.C.E.), 41, Spring Gardens, Manchester.
Sealed Tenders addressed to the undersigned and endorsed "Tender for Oil Dock," should be delivered at this Office on or before 10.0 a.m. on Thursday, May 15th.
41, Spring Gardens, Manchester. F. A. BYRE, Secretary. U 199

G. R.

BY DIRECTION OF THE DISPOSAL BOARD

RAILWAY MATERIAL
FOR SALE BY PUBLIC TENDER.

Tenders are Invited by the

Controller, Railway Material Section, Room 11, Armament Buildings, London, S.W. 1, on or before the 17th APRIL, 1919, for PART or ALL of the LIGHT RAILWAY MATERIAL, and on or before APRIL 19th for the 75 lb. RAILS in the following lists:—

LYING AT THE R.R. TRANSPORTATION DEPOT, PURFLEET, ESSEX.

20 lb. TRACK—60 cm. GAUGE.	Quantity.
Straight Rails, 5 m. lengths	90,269
Ditto, 2½ m. lengths	94,671
Curved Rails, 30 m. radius, 2½ m. lengths, inner	6,998
Ditto, outer	7,564
Ditto, 5 m. lengths, inner	9,348
Ditto, outer	9,363
Ditto, 30 m. radius, 5 m. lengths, inner	12,608
Ditto, outer	9,924
Ditto, 100 m. radius, 5 m. lengths, inner	3,337
Ditto, outer	2,846
Complete Turnouts, right hand	4,088
Ditto, left hand	4,181
Fishplates ... pairs	208,460
Steel Sleepers	231,441
Steel Sleeper Plates (for Rugeroni Raft Track)	9,964
Turntables	6
Level Crossings, 45°	44
Ditto, 60°	44
Ditto, 75°	44
Ditto, 90°	41
Dogspikes, Standard Pattern (5,295 bags)	1,809,138
Fishbolts (867 bags)	537,671
Rail Clips (3,253 bags)	1,965,163
Clip Bolts (6,361 bags)	3,564,150

60 cm. GAUGE ROLLING STOCK.

20 HP. "Simplex" Petrol Tractors	98
40 HP. "Simplex" Tractors	33
"Hudson" Steam Locomotives, 0-6-0	3
"Hunslet" Ditto, 4-6-0	32
"Baldwin" Ditto, 4-6-0	20
"American" Ditto, 4-6-0	1
"Westinghouse-Baldwin" Electric Mining Locomotive	1
Bogie Low Side Open Wagons (with Tarpaulins)	829
Bogie Well Wagons (with Tarpaulins)	55
Bogie Water Tank Wagons (without Tanks)	11
Bogie Covered Goods Wagons	13
Ditto (Bodies only)	11
Ditto (Bogie only)	1
Heavy Steel Double Sides Tipping Wagons (1 cubic yard capacity)	447
Four-wheeled Open Box Wagons	363
Four-wheeled Ration Wagons	2,356

LYING AT WIDNES FOUNDRY CO., LTD., WIDNES.

STEEL PRESSED SLEEPERS (Uncoated and Unholed).	
4 ft. 0 in. lengths	5,630
4 ft. 5 in. lengths	6,000
5 ft. 3 in. lengths	6,000
6 ft. 2 in. lengths	6,000

4,000 tons 75 lb. F.B. Rails B.S.S., at MIDDLESBOROUGH, care of Embarkation Officer.
180 tons ditto, at NOTTINGHAM, Messrs. Taylor Bros.' Works.

The Controller does not bind himself to accept the highest or any Tender. Tender forms with orders to inspect may be obtained on application to the RAILWAY MATERIAL SECTION at the above address. U 208

G. R.

FLOATING DOCK.
FOR SALE.

The Admiralty has for Sale

A FLOATING DOCK, with a total lifting capacity of 11,000 tons.
The Dock is under construction in the United Kingdom and is nearly completed.
Forms of Tender and permission to inspect can be obtained on application to the DIRECTOR OF CONTRACTS, Room 79, West Block, Admiralty, London, S.W. 1. U 119

DUBLIN CORPORATION.
WATERWORKS COMMITTEE.

TO CONTRACTORS.

NEW RESERVOIR, ROUNDWOOD, COUNTY WICKLOW.

The Waterworks Committee invite

Tenders for the Completion of

the CONSTRUCTION of an EARTHWORK EMBANKMENT and other incidental Works in connection therewith situated on the Vartry River in the County of Wicklow. Plans may be seen and Forms of Tender, Conditions of Contract, Specification and quantities can be obtained on and after Wednesday 30th day of April, at the office of MR. MICHAEL A. MONTHAM, Engineer in Charge, 28, Castle Street, Dublin, between the hours of Ten a.m., and Five p.m. (on any lawful day), Saturdays Ten a.m., to One p.m., on payment of a fee of Five Guineas which will be returned on receipt of a *bona fide* Tender.
There is upon the site certain plant which will be at the disposal of the Contractor, consisting of steam locomotives, steam cranes, steam navvies, waggon, rails, &c., and any firm tendering should visit the site and inspect the work already completed and examine the Plant upon the ground.
The Waterworks Committee will not be responsible for any cost whatever which may be incurred by parties who may send in Tenders or for any expenses they may undertake preparatory to or in connection therewith.
Contractors will be required to agree to the condition that no Tender shall be amended or withdrawn before the expiration of a period of two months from the date of delivery to the Corporation.
The Corporation will require the Contractor whose Tender may be accepted to employ Trade Union labour and to pay not less than the minimum standard rate of wages paid upon Public Works in the District and to employ regular tradesmen and to observe the hours and conditions of employment now recognised as proper there.
The workshop or workshops, factory or factories, or other places used by the Contractor in the execution of the Contract shall be open to inspection at any time during working hours by a duly authorised representative of the Trade affected by such Contract upon the production of a permit signed by the Town Clerk or other Officer appointed by the Waterworks Committee.
The accepted Contractor must pay the cost of the Deed of Contract, which will be Solicitors costs out of pocket only.
Tenders, endorsed "Tender for New Reservoir Embankment, Roundwood, Co. Wicklow," and enclosed in a sealed envelope addressed to the Chairman, Waterworks Committee, should be delivered at the Office of MR. CHARLES POWER, Secretary, Waterworks Committee, not later than Eleven a.m. on TUESDAY, the 13TH of MAY, 1919.
The Committee do not bind themselves to accept the lowest or any Tender.
The Contractor will be required to enter into a Bond with two sureties for the due performance of the Contract.
(By Order),
CHARLES POWER,
Secretary.
City Hall,
Dublin.
10th April, 1919. U 241

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A. C. BOYDE,
Director of Education and Secretary.
Education Office,
North Lodge, Darlington.
April, 1919. U 44

THE DYNAMICAL BALANCE OF RECOILING PARTS IN HEAVY GUN CARRIAGES.

By G. M. RUSSELL, B.Sc., Wh.Sch.

IT is proposed in the following note to draw attention to a result of the dynamical treatment of recoil as applied to the type of carriage commonly used for mounting heavy naval guns (see ENGINEERING, March 22 and 29, 1907, July 9, 1909, July 31, 1914). It can be shown that the carriage possesses an objectionable feature inseparable from its form, and that the adoption in its place of a dynamically balanced type of carriage would result in improvement as regards (*a*) accuracy of fire, and (*b*) the value of the stresses to which certain parts of the carriage and supporting structures are subjected.

The form of carriage above referred to consists virtually of a deep beam rotating about an axis perpendicular to its plane through the trunnion centre, and on the top boom of which slides the cradle to which the gun is rigidly attached. The sliding (*i.e.*, recoiling) parts are attached to the non-sliding (*i.e.*, merely rotating) parts by restraining connections which, while capable of yielding during recoil, are so arranged as to exert a resisting force of approximately constant magnitude. This resisting force, hereinafter referred to as Q, is made up of the addition of several parallel component forces, viz., that from the recoil cylinder, that of the run-out gear, friction, and the resolved part (positive or negative according as the gun is depressed or elevated) of the weight of the recoiling parts. Although every effort is, of course, made in this type of mounting to keep Q constant during recoil, it very rarely is so. That part of it, for example, contributed by the friction is particularly variable with dynamically unbalanced recoiling parts. For the present purpose, however, it will be sufficient (although not essential) to regard Q as constant at its average value as obtained from the internal ballistic conditions in the semi-graphical manner described by Lissak ("Ordnance and Gunnery," page 283).

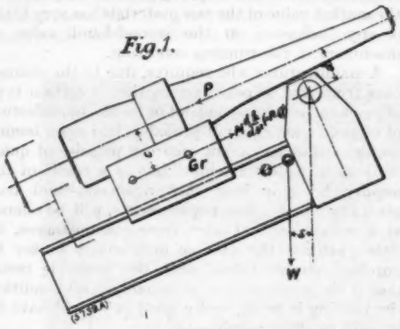


Fig. 1.

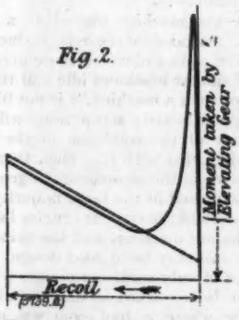


Fig. 2.

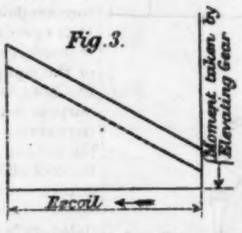


Fig. 3.

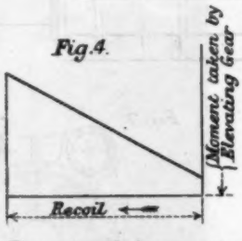


Fig. 4.

The point about the above described "slide beam" form of carriage, to which it is desired to draw attention, is that the cradle and other parts which are attached to the gun and recoil with it are wholly beneath the gun, their centre of gravity being something like 2 calibres below the gun centre line; and as these additions may amount to 10 per cent. or 12 per cent. of the weight of the gun, it follows that the centre of gravity of the whole recoiling mass may be about ¼ calibre below the gun centre line. It will be seen, therefore, that unless the resultant of the powder forces and Q passes through the centre of gravity, there must be, during periods of acceleration, a tendency to rotate about that centre, and it is the effect of the couple which must be set up in order to resist this rotation which must be examined. The few inches represented by the above-mentioned eccentricity of centre of gravity, have probably been assumed in the past to have no more than a slight effect of ensuring that the moment on the carriage should not change sign during recoil. The elementary demonstration and example given below will, however, show that, in spite of the small value of this dimension, it has the result, in conjunction with the large magnitude of the forces involved, of setting up at the initial part of the recoil moments which are very large in amount. The condition of non-changing sign of moment on the carriage during recoil, will in many cases be secured statically by the weight distribution of the carriage; if not, the best method of adjustment is, as will be shown below, by slightly lowering the position of trunnion centre with relation to the gun centre.

It is proposed to treat the question from the point of view of the carriage as a whole, and to examine only the couple which is transmitted to the mounting *via* the elevating gear and trunnions. The reactions between cradle and slide, which are internal to the carriage as a whole, will not be considered here, since expressions for them are given in the various text books, and the effect on them of a variation in the position of centre of gravity can be readily determined. It may, however, be noted that these expressions show that if the centre of gravity of recoiling parts be brought into the centre line of gun, this change alone (other conditions remaining as before) would modify that reaction which is taken by the cradle clips in this type of carriage to the extent of reducing it to a very small percentage of its former value, or even, in some cases, to zero.

For the present purpose, however, it will be sufficient to find the moment about the trunnion centre, which at any instant must be resisted by the elevating gear. The external forces acting at any instant, and whose effort to turn the whole carriage about the trunnions must be so resisted are shown in Fig. 1, in which P is the total powder pressure, the amount of which at any instant is known from the internal ballistic conditions of charge, &c.; M the mass, and $M\frac{d^2x}{dt^2}$ the reversed effective force of recoiling parts applied at their centre of gravity.

Taking moments about the trunnion centre for whole carriage:

$$P\,d + M\frac{d^2x}{dt^2}(c-d) + W\,s = E\,e$$

where E *e* is the moment of the elevating gear.

Now since the recoiling mass is being forced back by P and restrained by Q, it follows that its motion is given by:

$$M\frac{d^2x}{dt^2} = P - Q$$

Hence the numerical value of $M\frac{d^2x}{dt^2}$ is known at any point of recoil.

∴ Substituting in the equation of moments we get:

$$P\,d + (P-Q)(c-d) + W\,s = E\,e$$

or

$$P\,c - Q(c-d) + W\,s = E\,e \quad . \quad . \quad (a)$$

Now, since the gas pressure upon which P depends may, when at its maximum, reach a value between 18 tons and 20 tons per square inch, it is evident that the magnitude of P (= pressure × area of bore) is very great and many times that of either of the other forces included in the left side of equation (*a*). The value of E *e* is therefore controlled, at the initial parts of recoil, by the value of the term P *c*. Shown graphically, the conditions expressed by equation (*a*) will be somewhat as in Fig. 2, which shows how the moment to be resisted by the elevating gear varies when plotted on a base of recoil.

If now in equation (*a*), *c* be made = 0 (*i.e.*, centre of gravity of recoiling parts on gun centre line), the relation reduces to:

$$Q\,d + W\,s = E\,e \quad . \quad . \quad . \quad (b)$$

which is independent of P.

The conditions expressed by equation (*b*) are shown graphically in Fig. 3.

Equation (*b*) also shows that if conditions of accessibility at breech, &c., cause the gun in the run out position to be so far forward that W *s* is negative at the initial parts of recoil, then E *e* may still be kept positive by giving *d* a value sufficient to ensure that Q *d* − W *s* is positive. Hence the statement previously made, that the correct method of adjustment to ensure non-changing sign of moment during recoil is by slightly lowering the trunnion centre relative to the gun centre.

If, finally, *d* be also made = 0 equation (*b*) reduces to:

$$W\,s = E\,e \quad . \quad . \quad . \quad (c)$$

which shows that when both trunnion centre and centre of gravity of recoiling parts are on the gun centre line the only effect of recoil on the elevating gear is that due to the merely statical effect of the changing position of the recoiling weight; see Fig. 4. It may be noticed that it has not been necessary to use the *position* of the line of action of Q. It influences those forces only which are internal to the carriage as a whole, such as the reactions between cradle and slide, and, except in so far as the value of Q may be slightly modified by the frictional forces (= μ × reactions), does not affect the overall moment which alone we are here considering. Therefore, very little alteration of the latter can be made by raising or lowering the position of the buffer, &c. A similar statement can also be made with respect to the position of the sliding surfaces relative to gun.

We have therefore the following result: That owing to the centre of gravity of the recoiling parts of the slide beam type of naval carriage being below the centre line of gun, the carriage is subject to a very large, suddenly-applied moment, tending to turn it in elevation; and that this occurs while the projectile is in the bore; also that this large initial moment can only be eliminated by arranging that the centre of gravity of recoiling parts is on the gun centre line—a modification impossible to make in this type of carriage.

If the elevating gear and its supports were perfectly rigid this moment could have but slight effect as regards movement about the trunnions. But in the turret mountings the turntable structures, being composed of mild steel-riveted platework, and supported on roller paths of large diameter, are by no means inelastic; and although the large moment of inertia of the carriage about the trunnions opposes any large movement in the short time during which the moment acts, it is nevertheless clear that the same accuracy of fire cannot be expected with a mounting of this type as with one in which the initial moment in question is non-existent. Apart from its effect on the mounting it is probable that the moment would set up in the gun itself vibrational "whip" in the plane of elevation; the effect on the projectile would therefore depend on the particular phase of the vibration when it leaves the bore—a factor which would probably be different for each gun and mounting.

In order to show what order of value may be attained by this initial moment when at its maximum in an actual example, consider a carriage of the slide beam type suitable for a gun of 13·5 in. calibre, with the following roughly approximate data:

Weight of recoiling parts = 80 tons.
Weight of whole carriage and gun = 100 tons.
Recoil = 36 in., Q = 250 tons, *d* = 2 in. *c* will be about 2½ in.

If pressure be taken at 19 tons per square inch

when at its maximum, then P = 2720 tons. Assume also that there is a slight breech preponderance of weight of whole carriage when gun is run out, and that s is 3 in. behind the vertical through trunnion centre at commencement of recoil.

Then using equation (*a*) we find that $E\,e = 608 + W\,s$ when P is at its maximum; so that at this instant the moment to be resisted by the elevating gear is increased by the dynamical effect by 608 tons-ft. over and above that due to the statical moment only. The total moment when at its maximum is therefore about 635 tons-ft. The curve with highest point on Fig. 5 shows the moment on the elevating gear plotted on a base of recoil. The remaining curves on the same figure show how the decrease of distance of centre of gravity from gun centre line in successive steps flattens the curves until the initial irregularity has been entirely removed when the centre of gravity is on the gun centre line.

As regards the stresses set up, it is to be observed that the large moment in question is transmitted from the cradle to the slide by means of a downward thrust at the rear of the cradle and an upward pull at its forward end, the latter compressing the cradle clips; any reduction, therefore, in the magnitude of the moment would have the effect of relieving the clips of the severe compressive stress to which they are at present subjected at the initial parts of recoil. The elevating gear, of whatever form, would, at the same time, also be relieved of initial shock. It may further be pointed out that as the turret as a whole and the ship's structure have to transmit the forces set up by the extra moment, they

Fig. 5.

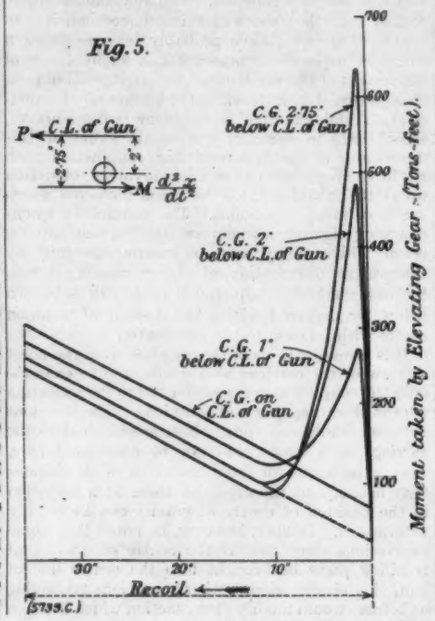
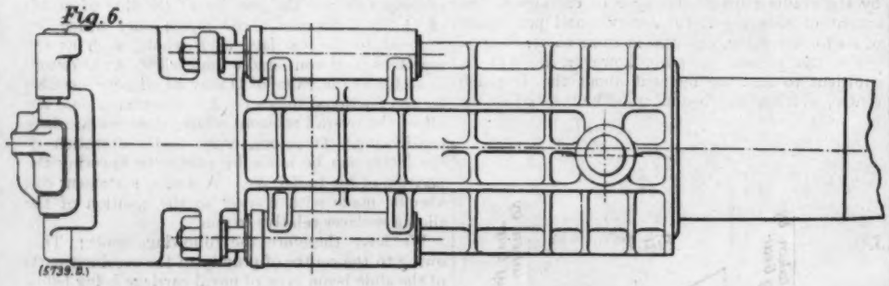


Fig. 6.



also are thrown under additional stress, which may be avoided by correct design.

The method commonly employed for determining the stresses, &c., on the turntable structures, roller paths, &c., is by working on the assumption that they are set up by Q acting along the centre line of gun. It may here be mentioned that this is only correct if the centre of gravity of parts is on the gun centre line; and that when the mounting is fitted with a carriage of the slide beam type the assumption leads to a considerable underestimate of some of the stresses. For the external forces at any instant are, as has been shown, the two unlike parallel ones P at the gun centre, and P − Q at the centre of gravity of recoiling parts. The resultant of these is Q at a height above gun centre line $= \frac{P - Q}{Q} \times c$.

Q should therefore not be applied at the gun centre but at a distance $\frac{P - Q}{Q}\,c$ above it. In the 13·5-in. example above, this amounts, when P is a maximum, to:

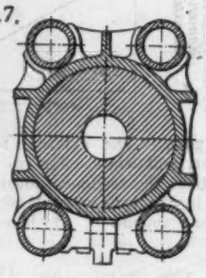
$$\frac{2{,}720 - 250}{250} \times 2{\cdot}75 = 27{\cdot}2 \text{ in.}$$

The assumption in this case that Q is applied along the gun centre line amounts to ignoring a moment of:

$$250 \times \frac{27{\cdot}2}{12} = 566 \text{ tons/ft.}$$

As regards carriages for the heavier naval guns which are free from this want of kinetic balance, the type which very approximately satisfies the conditions (and could be designed accurately to do so) is that sometimes employed in certain foreign services. In this the gun is finished with a cylindrical external surface long enough to slide during recoil in a tubular cradle after the manner of many smaller mountings (see Figs. 6 and 7). The

Fig. 7.



recoil cylinders and run-out cylinders would be symmetrically disposed top and bottom of the cradle in such a manner that the centre of gravity of the recoiling parts is either on, or very close to, the gun centre line.

FERRO-CONCRETE SHIPBUILDING IN NORWAY.—The building of ferro-concrete vessels in Norway started under what appeared to be very promising conditions. The first ventures were apparently successful, and consequently new yards were started in several places. There were, however, some sceptics, who recommended a certain amount of caution, and it now almost looks as if their misgivings were not unreasonable. The *Gothenburg Journal for Commerce and Shipping*, which is generally well-informed, contains in a recent issue, a communication from Christiania, stating that it has for some time been known in well-informed circles, that several of the Norwegian ferro-concrete shipbuilding yards were in a very precarious position. One yard is already under what is called private bankruptcy administration, and it is expected that several other yards will be compelled to close down or reduce production. The reason for this state of affairs is that the construction of ferro-concrete vessels has proved far more costly than was estimated; more, in fact, than the construction of corresponding vessels of steel would have done.

SECOND-HAND MACHINERY.

ATTENTION has recently been drawn to the great fluctuations in the prices which are being obtained, or which are offered, on the sale of machine tools and plant released as a consequence of the armistice and the resulting decline in the number of orders placed for war stores in the National Factories and with engineering firms who have increased or supplemented their equipment of certain types of machines in order that their output might be augmented, or to balance the operations for the required output. In some cases the prices realised are reported as being high, and were therefore considered satisfactory, whilst in others only scrap values have been offered and accepted.

It is only natural that such a state of affairs should exist, as there are many factors which operate in determining the price given for second-hand machinery. Just prior to the armistice the governing factor was one of demand and supply, as machine tool makers were then not in a position to give anything like prompt deliveries even on the highest priority certificate. At the present time the conditions have not improved much and, further, the market value of the raw materials has very little, if any, influence on the second-hand value of machinery in fair running condition.

A manufacturer who requires, due to the change-over from war to peace production, a certain type of machine to increase output or for the manufacture of a specific article, will probably find upon issuing inquiries that he cannot secure a promise of quick delivery of a new machine, but as a result of the inquiry he may hear that a second-hand one, generally meeting the requirements, will be offered at a certain sale. Under these circumstances, he either attends the sale or instructs a broker to purchase on his behalf with the probable result that if the machine is in reasonably good condition the bidding is brisk, and a good price will have to be paid to effect purchase.

In another case the machine offered at a sale may be a "special," intended for the bulk production of a war store and of a class of which there may be quite a number of similar machines idle and therefore available. For such a machine, it is not likely that more than approximately scrap value will be realised, irrespective of the condition of the tool or the equipment included with it. Then there is the more common case of the commercial or general purpose machine tool used in the large majority of engineering shops, such as the standard engine lathe, the milling and planing machine, and the grinder, the tool offered for sale may be of good design, but in poor condition or of only mediocre design, while further it may have been worked on day and night shifts in a factory where a tool-room was non-existent.

In such cases the price obtained at a sale depends upon the number of similar second-hand machines upon the market, the condition of the machine, the knowledge of the would-be purchaser as to the value of the tool, the locality in which the machinery is installed, and the estimated expenditure necessary to dismantle, transport, and re-erect it on its new site.

The works manager has to consider all these points before deciding to purchase, while he is more or less forced at the present time, to take a second-hand machine if prompt delivery is essential. The urgency of the demand is in such a case the controlling factor, and in a great measure accounts for the unstable prices. From some examples seen recently it would appear to be very necessary to act with caution in such cases, especially when prices are being run up at a sale. Whenever circumstances permit, it is sounder policy to purchase a well-designed and accurate new machine, whether of the commercial or special type, than to obtain hurriedly a second-hand machine which has most probably been used heavily on day and night shifts by unskilled labour for the production of war stores; such machinery will presumably have received but scanty attention, and only have been repaired after a breakdown. The cost of putting the machine in repair, of adapting it to meet the new requirements, of dismantling at works at a distance from the purchaser's works, and its re-erection, have, as

above stated, to be added to the price paid for the machine or plant.

The prudent manager will not pay high prices for second-hand machinery if he can by any means procure new, up-to-date and efficient machines to assist him to meet the keen competition which will have to be faced for some time to come. In this competition accurate semi-automatic, full automatic and, in some cases, single-operation machines in conjunction with all kinds of labour-saving and assisting devices, will play a most important part. Bearing these facts in mind, if a works owner or manager is obliged to purchase a second-hand machine, it is important that he should as promptly as possible have the probable useful life of such a machine ascertained in order that the proper charge may be levied against it annually to cover the depreciation and obsolescence rates due to its class.

TEMPLETS, JIGS AND FIXTURES.—No. XXIII.

By Joseph Horner.

There are no machines for which so many fixtures and jigs have been designed in the form of integral attachments to the tables as those for drilling, and boring, and their employment extends. The simpler jigs are appropriated largely by these machines, and also the fixture combined with the jig. Many of the machines themselves are primarily designed, or else modified, to adapt them to deal with highly repetitive jig work. These employ single or multiple spindles, arranged in gangs, that is, in line, either for the work of multiple drilling, or very often for successive drilling, reaming, boring, tapping, arboring, facing, turning. For multiple drilling of another kind, machine spindles are arranged in circles, or rectangular patterns, or irregular clusters. The single-spindle machines are often arranged in their units to form a gang, to accomplish a sequence of operations in charge of a single, or separate attendants. The multiple spindle designs are commonly in charge of one attendant. The cluster machines may be performing the same class of operations simultaneously, or those of a diverse character. The spindles are generally under the direct control of the operator, but in some advanced designs they are controlled automatically, leaving the attendant free for loading and unloading the work. A good many machines again are provided with turrets to hold the tools for performing a sequence of operations, as drilling, reaming, facing, tapping, &c.

The immense sphere occupied by jig and fixture work on various designs of drilling machines is due to the fact that these are, like the lathe, tools capable of accomplishing many functions. There was nearly as much of variety in the tasks imposed on these machines years ago as there is now, but the present performances are much more precise, consequent on the employment of jigs and fixtures, and vastly more rapid because of the sub-division of duties, and the speeding-up of drills, and other tools. A drilling spindle will bore holes of small diameters with inserted cutters. It will face, or arbor, or counterbore, will turn the outsides of small bosses after drilling or boring them, will ream and tap. Its performances, therefore, run very closely those of the turret lathes and automatic screw machines. This explains the extensive vogue of these machines in many and varied groups of manufacture, notably of late in automobile work, and in the tooling of the smaller shell cases, and of fuse parts. Holding the work in a fixture, it can be brought underneath successive spindles, or separate spindles may be brought into joint action, each armed with different tools.

Indexing fixtures combined with drilling jigs are necessary adjuncts for much of this work. The indexing is usually done with a spring pin entering holes in a face, or with a latch entering notches in the periphery of a disc, the holes or notches being set at a radius at least as large as the radius on which holes have to be drilled. The work being carried suitably according to its shape, is presented underneath the drill as often as the pin or latch is dropped in hole or notch respectively. The drill is controlled either through a bushed jig that forms a portion of the work-holding fixture, or through an independent guide attached to a section of the machine. If the product is large, fixtures may be duplicated for use on gang machines. Or a single fixture can be bushed for successive operations, as drilling and reaming.

The use of fixtures under multiple-spindle drills is made, when practicable, to subserve economy in loading and unloading. Thus, it must often happen that one operation will occupy more time than others. Drilling a hole will take more time than reaming the same hole, or than tapping it, or than facing a boss, or than chamfering an edge. Some holes will be deeper than others, or larger. Having multiple-spindle machines, pieces can be loaded and unloaded under the spindles in which tooling is completed, while the longer operation is proceeding. Examples of this kind are illustrative of that class in which the work about a single hole is divided among tools held in different spindles, as an alternative to the method of changing the tools themselves in a single spindle—the old way. It resembles the work done with tools brought round in a turret.

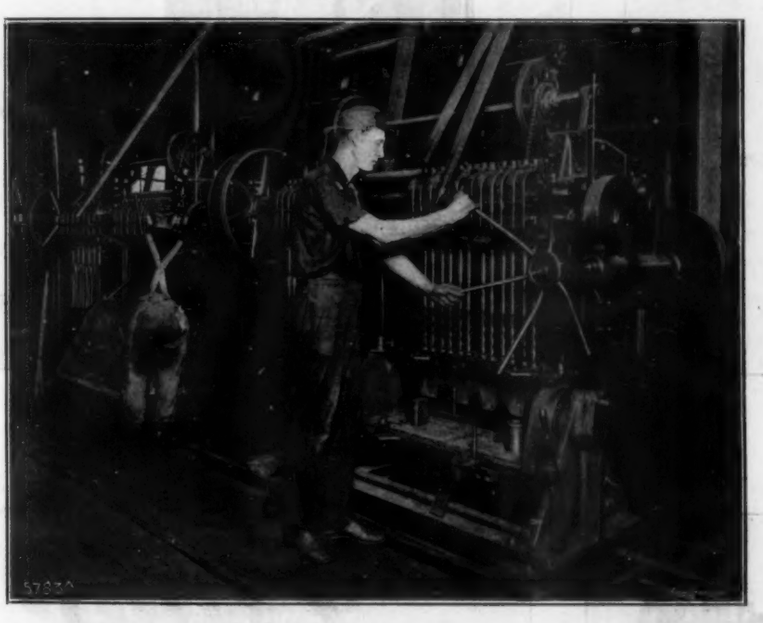


Fig. 654. Multiple Drilling Machine; Moline Tool Company, Moline, Ill., U.S.A.

Since, for the performance of operations of different kinds, variations in speeds and in feeds are required, it is better in such cases to transfer the work between separate machines disposed in gangs, than to use those multiple spindle types in which the spindles all run at the same speed. It is not always necessary to instal an attendant at each machine, since the relative lengths of the operations, and the character of the work may well permit of a man looking after three or four machines. An advantage of the single-spindle design arranged in gangs, is that if the tool meets with an accident, and is temporarily thrown out of action, it stands alone, while if the same thing happens in a multiple-spindle machine, it is put out of service.

The largest economies of drilling, and the operations that are allied to it, are secured when the cluster-spindle machines are designed specially for dealing with one product. A good many such have been built. In these the centres of the spindles are not made capable of adjustment, but are fixed to suit only the standard work to be repeated for a lengthy and indefinite period. Again, the spindles are not speeded alike from the main drive, but each has its own most appropriate speeding, as required for drilling, or reaming, or tapping, or for smaller or larger drills. Feeds are varied also, and are frequently provided for with cams, with quick return to withdraw the tools from the work, and with other useful provisions. In some of these machines the drill spindles occur with vertical, with horizontal, and with angular axes, with enormous resulting output. All the holes in a piece of work may thus be drilling, or undergoing other treatment at one time. In one multiple-spindle machine 480 crank cases have been drilled in eight hours, each case having had 84 holes drilled at a single setting.

The case of fixtures and fixture-jigs extraneous to the machines, yet designed in association with them includes that of a rather large group in which these are run along on rails under a battery of machines. An illustration of this kind was given in a previous article (December 27, 1918, p. 733), where the work done was that of boring automobile cylinders. The same method is largely adopted in connection with multiple-drilling under batteries of machines, to which the work is transferred along rails (Fig. 654). The details of these designs vary with the character of the work. Provision is made for turning the work about in trunnion bearings to bring holes situated at different angles under the drill spindles. These expensive arrangements are justified if a large output is required. Some limit must be set to the multiplication of machines in gangs. Not altogether, when the output is large, because of the capital outlay, but on account of other considerations, as that of shop floor space occupied, and, chiefly that of the interdependence of machines, which results in delay in the case of a break-down of one unit, or the temporary absence of an attendant.

Figs. 654 to 658 are examples of multiple drilling done on machines by the Moline Tool Company, of Moline, Illinois, U.S.A. The spindles are used on a range of work held in a single fixture, or in more than one, so that loading and drilling can be going on at the same time. Variations are made in the manner of feeding. In the machine shown by Fig. 654, the spindles are fed, in the others the table is fed. Although in almost all cases the drilling jig is attached either directly to the work or to the work-holding fixture, yet this method may be abandoned in favour of making the jig an integral part of the machine. In Fig. 655, the jig support is fitted to the pillar of the machine, to steady and guide the drill spindles above the surface of the work, which is that of drilling holes in pipes. In this example, the feed is imparted to the table through a cam, operated with a spider wheel. When the table is lowered, the pipes are readily unloaded and reloaded. The table is counter-weighted, and weights can be increased or diminished, with alterations in the weights of the fixtures and work carried. The heads are adjustable for centres. Each tool has its supply pipe for lubricant.

Fig. 656 shows a four-spindle machine in which

MULTIPLE DRILLING MACHINES.

CONSTRUCTED BY THE MOLINE TOOL COMPANY, MOLINE, ILLINOIS, U.S.A.

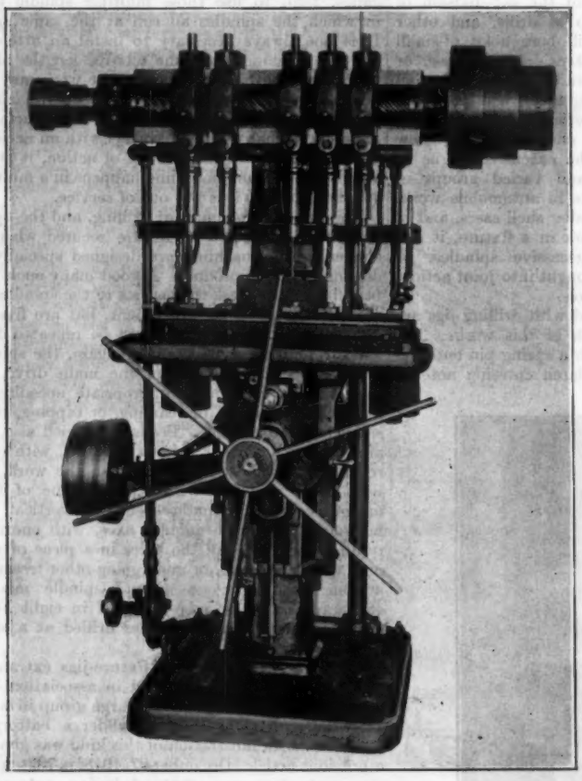


FIG. 655.

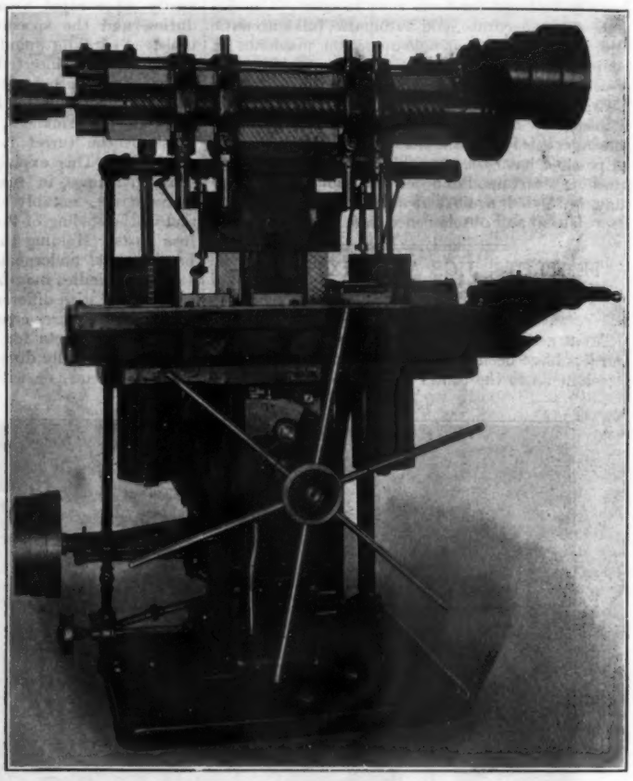


FIG. 656.

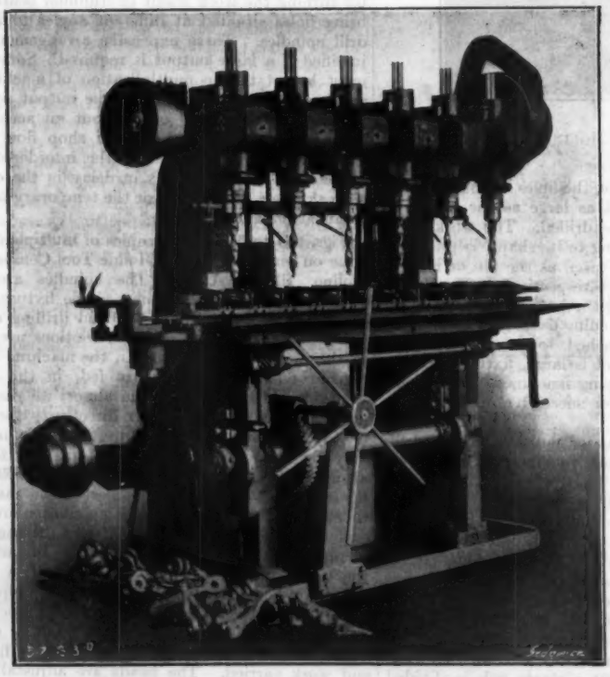


FIG. 657.

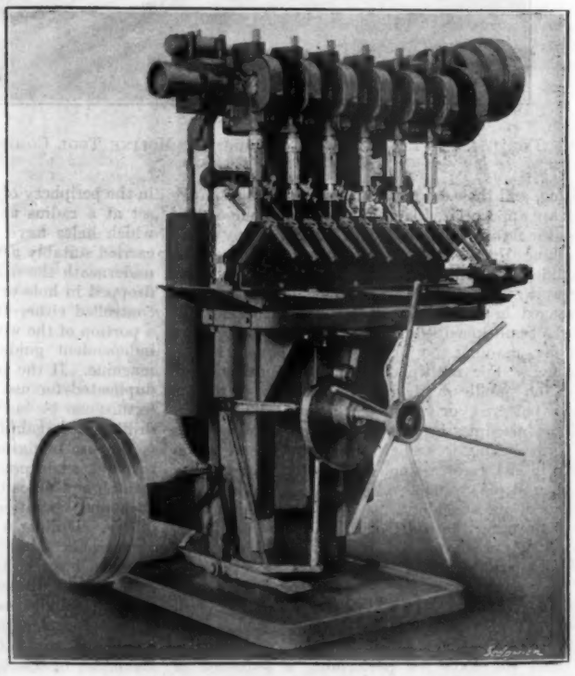


FIG. 658.

a cam feed is provided for the table. The spindles here are being used in pairs. Four fixtures are shown on the sliding table, which is indexed for longitudinal setting. Work is proceeding on two fixtures, while the attendant loads the other two. The class of work for which this is designed is that of small drop forgings and castings.

The illustration, Fig. 657, is that of a fixture for multiple tooling on a dozen freight-brake rod-knuckles, all being mounted simply on one fixture, which is carried on the table of the machine. A heap of the knuckles is seen lying on the ground beside the machine. Six drills operate on alternate forgings, while the attendant is loading the alternate stations. Upright pins on the fixture flank the tails of the knuckles and prevent them from turning under stress. At the left-hand end a crank and latch are

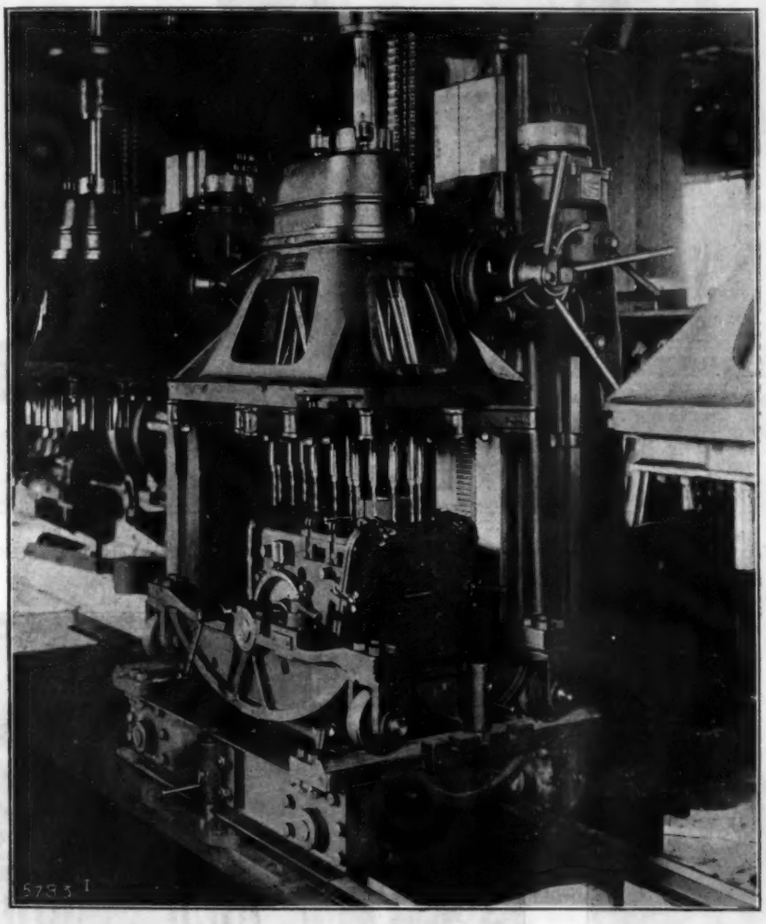


Fig. 659. Fixture for use on Cluster Spindle Type Drilling Machine; Messrs. Edwin Harrington, Son and Co., Inc., Philadelphia, Pa., U.S.A.

fitted, by which the two series of knuckles are indexed under the drills in turn. A single spiral is used for driving the spiral gears on all the spindles. The table is fed upwards by two roller cams, seen on a shaft in the base, which shaft is turned through the spider wheel and worm gear. Cams are designed to suit the work. In this instance the shape is such that the drills are forced quickly through the gap between the webs of the knuckles. It will be observed that the cams are provided at intervals on their peripheries with several shallow notches. The object of these is to relieve momentarily the pressure on the drills, break the chips, and admit lubricant, the feed pipes for which are seen. This is done only on steel, being unnecessary on cast-iron and brass work. In some cases where a feed for facing is included, a pause or "dwell" is provided for the purpose of cleaning off the tool marks from a face. Note may be made of the fact that the flat-twisted form of drill is being used. It is one which gives better results on some classes of work in steel than the solid twist drills afford.

Another example of a table cam feed, but with a single cam in front on a single column design of machine, is shown in Fig. 658. This is being used for the multiple-drilling of pin holes in levers mounted at an angle in a fixture set on the table. Six spindles are operated at one time, so that twelve pin holes are drilled in two sets of operations. The cam is driven from a large three-stepped belt cone, through worm gearing at the rear. The spider wheel in front imparts 4 in. of vertical adjustment independently of the feed, to suit fixtures of different depths. The table is counterweighted, one of the two weights being seen beside the column. It has an automatic stop and quick return. The periphery of the cam is notched as in the previous example, and for the same reason. In this and other machines the sliding jig plates permit of fitting jigs of various kinds to accommodate a variety of articles.

An example of a fixture designed for use under machines of the cluster-spindle type is shown by Figs. 659 to 661; the fixture and the machines being by Messrs. Edwin Harrington Son & Co. Inc., of Philadelphia, Pa., U.S.A. Originally, this class of machines was designed for drilling all the holes in the flanges of cylinders and pipes, with provision for making a moderate range in the centres. Consequently, the vertical drill spindles are driven through universal jointed connections by means of gears from a central shaft, and are located and set for centres in radius bars. The spindle head is made in one with its saddle, and being very massive, its weight is counterbalanced with a weight inside the column, and an automatic safety device is provided to prevent it from falling if the chain should fracture. Heads are varied in shapes to suit the class of work done, being circular, square, or rectangular in plan. The number of spindles is also varied. The facility afforded for drilling a large number of holes simultaneously opens up wide possibilities. When to this is added the utilisation of a battery of such machines, and a roll-over fixture, such as that illustrated, the aggregate manufacturing results, and their bearing on keen competitive conditions does not need emphasising. These are facts that are going to weigh heavily in the coming years of reconstruction, and they will be in favour of those firms who handle specialities in maximum quantities.

The article illustrated is an automobile four-cylinder *en bloc* casting, with a moiety of the crank case. It is shown lying on the ground in Figs. 660 and 661, page 496. The jig-fixture designed for its reception is therefore a massive one. It is also elaborate, since it combines provision for drilling from four surfaces, which entails the rolling-over of the fixture. It includes a traverse along rails to bring it under three distinct machines, Fig. 660, with an arrangement for locking it in place under each. The locking pin is seen in front of the trolly in each illustration. There is also a movement of the fixture at right angles to the main track, so that two sets of operations can be performed under one spindle-head.

The base of the fixture is seen to be built up of rolled joists, with cast iron bosses to carry the axles of the truck wheels, the construction being similar to that of the crabs of overhead travelling cranes. The cross tracks are of truncated vee section, and the trolly wheels are turned to fit, a provision which prevents any lateral play between wheels and tracks. The girders for these wheels, which are castings, are connected by other girder-like castings of fish-bellied outline, that carry the trunnion bearings about the centre, on which the work-holding portion of the fixture is supported, and rolled-over by the internal gear with its pinion and winch handle. A drilling jig cover seen in the foreground in Fig. 661, and in its place in Fig. 659, is secured with eye bolts.

In connection with the work done on the gang and the multiple spindle drilling machines, the question of how to arrange for both drilling and reaming arises, and it is answered differently. Slip bushings are used, but as these entail the changing of the bushings in the jig plate, with consequent delay, the better plan is to use separate plates for drilling and reaming. In a case like Fig. 661, the substitution of one plate for another would be much more satisfactory than changing bushes in a single plate, and the method is frequently adopted. It may be worked out in more than one way. The plate can be changed bodily, using locating pins and eye-bolts. Or the jig-fixture can be made in two portions and dealt with on different machines adjacent. Or the work-holding fixture can be separate from the drilling and the reaming jigs, and enclosed in these by any means suitable to the character of the work, a sliding fitting being usual. The fixture is then taken from the drilling jig on one machine to the reaming jig on a machine adjacent. A method which is sometimes adopted in the case of shallow holes is to combine the drilling and reaming in one tool, using one jig. The drill is a short one, and the fluted reamer is at the rear, and is the guiding element fitting in the bush in the jig.

Rivals to the gang and cluster-spindle multiple machines are the turret drilling machines. In most of these designs the drilling spindles are carried on the faces of a turret, indexed round a horizontal axis, and driven from a central shaft, and bevel gears. For the turret the claim is made that only the drill or drills on one face, or spindle are running at one time, being thrown into action by a clutch; that the work is fed to the drills with a rising table with a range of feeds; that the table can be indexed past the drills, and that either a single fixture or several can be carried on the table, to be brought under the operation of drills, reamers, taps &c. That since six to twelve tools are carried in a turret, this is equivalent to as many distinct single-spindle machines, with resulting economy of floor space. When more than one fixture is used, loading can be going on at the same time as tooling. Since

MULTIPLE DRILLING MACHINES (CLUSTER SPINDLE TYPE) AND FIXTURES.

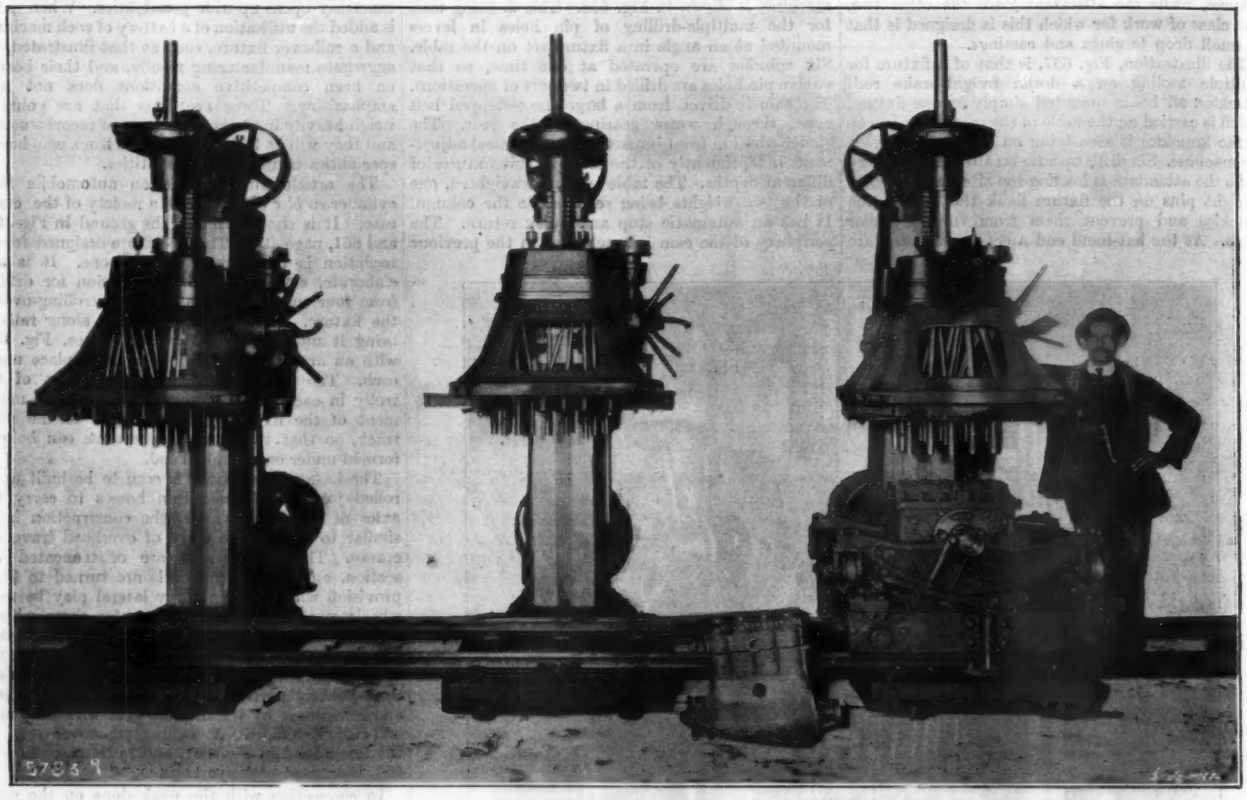


Fig. 660. Multiple Drilling Machines (Cluster Spindle Type); Messrs. Edwin Harrington, Son and Co., Inc., Philadelphia, Pa., U.S.A.

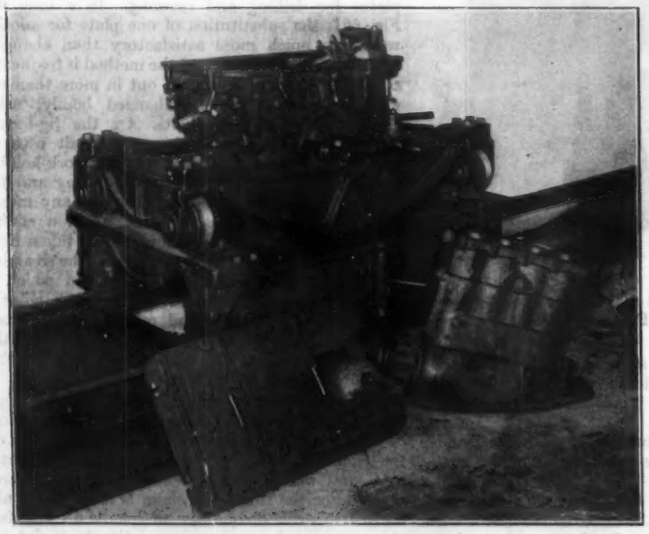


Fig. 661.

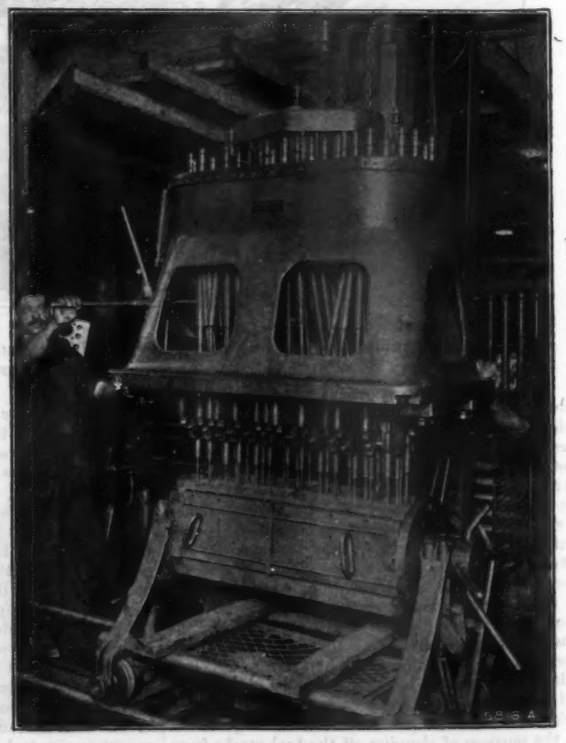


Fig. 662.

Fig. 661. Fixture for use in Cluster Spindle Type Drilling Machine; Messrs. Edwin Harrington, Son and Co., Inc., Philadelphia, Pa., U.S.A.

Fig. 662. Trunnion Jig used in Hudson Motor-Car Plant; National Automatic Tool Company, Richmond, Ind., U.S.A.

TEMPLETS, JIGS AND FIXTURES.

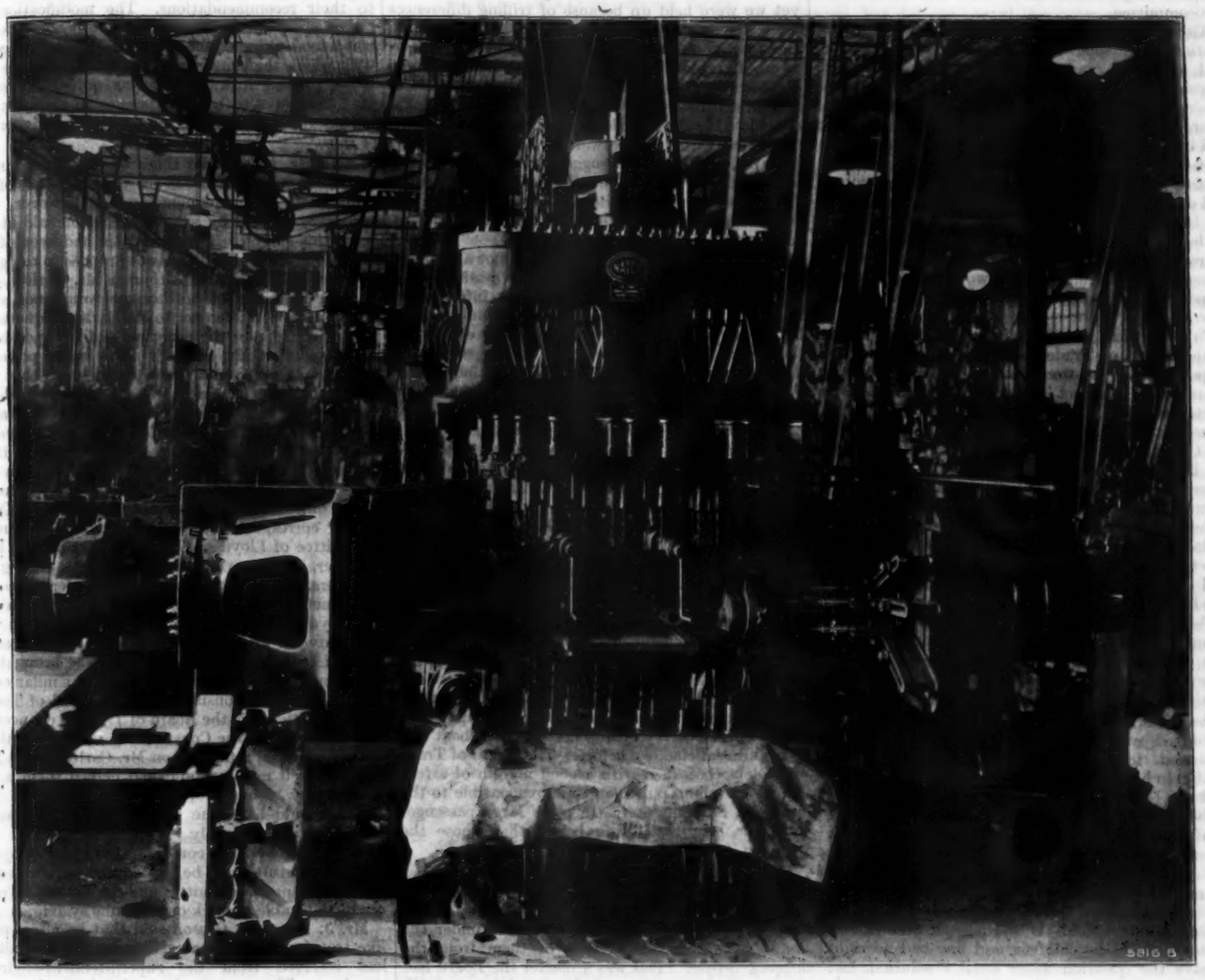


Fig. 663. Single-Purpose Multiple Drilling Machine; National Automatic Tool Company, Richmond, Ind., U.S.A.

spindles are driven with gears, these can be sized to suit spindle speeds, for drills of different sizes, reamers, taps, &c.

Figs. 662 and 663 illustrate multiple drills by the National Automatic Tool Company, of Richmond, Ind., U.S.A. Fig. 662 is a trunnion jig used in the Hudson motor-car plant, running on tracks to be used in connection with a battery of machines. Fig. 663 is a remarkable example of a single-purpose machine used in the Studebaker plant. It is a four-way machine, drilling from above, below, and at both ends, each battery being of the cluster design. Several installations of this kind are in operation working on the Liberty aircraft motor. In one case 70 turret lathe saddles are drilled in a day. In another, 12 drills of different sizes operate at one time, each at appropriate cutting speeds. Practice has, indeed, advanced a long way from the simple drilling templets of the old-time machinists.

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Continued from page* 481.)

At the opening session of the second day's proceedings of the annual meeting of the above Institution, which was held at 11 a.m. on the 10th inst., in the Hall of the Royal Society of Arts, Vice-Admiral Sir Henry Oram was in the chair.

Admission of Women.

The first business was concerned with a resolution permitting women to become members of the Institution on the same terms as men. The resolution was proposed by Sir William E. Smith and seconded by Sir Alfred Yarrow. Both speakers cordially commended the subject of the resolution and spoke of the good work which had been done by women during the war. Sir William Smith referred particularly to work done by ladies in connection with the experimental tank at Teddington, while Sir Alfred Yarrow said that the lines of his latest ship had partly been determined by a lady, Miss Keary. This ship had given 39·6 knots fully equipped on trial, which he believed was a record. Sir Alfred also said that on account of a joiners' strike at Scotstoun the whole of the joiners' work on a destroyer had been erected by women. They had made an excellent job, and the boat had been accepted by the Admiralty. He added that he had proposed that women should be admitted to the Institution about twenty-five years ago, and at that time barely got away with his life. Matters were changed now, and he would be very disappointed if the resolution was not passed without a dissentient voice. Sir Alfred had his wish in this matter, the meeting passing the resolution unanimously.

The British Marine Engineering Committee.

The next item on the agenda was a paper by Mr. A. E. Seaton, entitled "The Work of the British Marine Engineering Design and Construction Committee." The paper was read in abstract by the author. We need not deal with it here, as we reprint it in full on page 519 of this issue, but should say that Mr. Seaton made a slight correction from the text of the paper. It was stated at the beginning of the paper that the conception of the committee did not originate in the Institution. He had now found out that this statement was not correct. It did. In 1883, speaking after a paper read by Mr. Milton, Sir William Siemens actually definitely proposed such a committee. He said that if a uniform boiler code had been in existence it would have saved him the necessity for spending 10,000*l.* on having new boilers put into the cable ship Faraday.

Mr. D. B. Morison opened the discussion. He said the whole of the committee felt themselves much indebted to Mr. Seaton for the able report on their work which he had produced. The success of the committee had undoubtedly been largely due to their chairman, Mr. Seaton, and they were very proud of him. He need not refer to pre-war conditions as they affected boiler manufacturers, or dwell on the advantages of a single boiler code. The advantages were obvious, and it was a mystery why the matter had not been taken up before. The committee, the work of which was dealt with in the paper, was elected by the various marine institutions of the country. It had 28 members, including two professors, two consulting engineers, nine directors of manufacturing concerns interested, nine superintendent engineers of steamship companies, two directors of steel works, and the chief engineers of Lloyd's and other registration authorities, while the chief engineer of the Board of Trade took part unofficially. The assistance of the

superintendent engineers had been simply invaluable, and they had placed all the information at their disposal wholeheartedly at the service of the committee.

The text of the labours of the committee had been, in the first instance, safety, followed by efficiency and assisted by an adequate appreciation of the physical properties of metals and the influence of modern machine tools and manufacturing plant. There had been 30 meetings, and the attendance had been exceptionally good throughout, one reason probably being that they had all suffered from the present multiplication of codes. Many members had carried through special work for the committee, as, for instance, Mr. Hamilton Gibson, who had made a large number of tests. Mr. Milton had been a tower of strength, while Mr. Dantzie had proved a most able secretary. He would say that the proposed rules were completed and available last year.

To turn, then, to some comments on the relation of the Board of Trade to the committee and the proposed rules, he would say at the first that he did not wish to reflect in any way upon the Board's engineer-in-chief, Mr. Carlton. He would like to reflect, however, on the official position in which Mr. Carlton was placed. In January of this year the Board of Trade issued a leaflet modifying its boiler rules. The committee was, however, never informed that this step was contemplated, and the leaflet was not sent to a single member. In the works with which he was connected, a copy of the leaflet was handed to the chief draughtsman by the local surveyor. The chief draughtsman handed it to him, and that was the first time he heard of it. In the leaflet many of the recommendations of the committee had been adopted and test pressures had been modified. The rules still differed slightly however, from the proposals of the committee. He simply gave these facts without comment.

The great loss which the Board of Trade rules occasioned was owing to the thickness of metal demanded for the various pressures. It was possible to have a case in which Lloyd's rules would allow one to carry a pressure of 200 lb. which under the Board of Trade rules would have to be cut down to 149 lb. The matter was very serious in the case of new ships which it was desired so to build that they might carry passengers if necessary. In Australia he had known a case in which a ship had to have the boiler pressure so reduced that she lost ½ knot speed. If the matter were not so serious it would be childish, and one had no right to leave the question alone until a solution had been found.

After the issue of the Board of Trade leaflet the committee wrote to the Board about it and requested an interview. The reply received was so subtly phrased that it was impossible to say whether it was an acceptance of the proposal, or a refusal. Accordingly the committee tried again, and that time got a sort of half-hearted invitation. When the meeting took place, the representatives of the committee were received by two non-technical officials and Mr. Carlton. The officials were evidently experts in Parliamentary procedure, and proceeded to give the committee representatives a little tuition on that subject, which, however, was not what they had gone for. What he (the speaker) gathered from the interview was that the engineer-in-chief of the Board of Trade was, by virtue of his position, an autocrat. There was a consultative committee in existence in connection with the Board of Trade, but it had never been consulted. As a contrast to this there was a similar consultative committee in existence in connection with Lloyd's and it had been of great service to the Registry and to the country. What was wanted was for the Board of Trade to come out of its citadel and meet the Construction Committee in the open, so that all might join forces in the interests of the country.

He sometimes thought we were all colour-blind in reference to the problems of the future. They would be of unparalleled difficulty, and while other countries were organising and getting ready we were frittering away time. About a fortnight ago, when they were at the Board of Trade, it was understood that a meeting with their chief-engineer and others would take place. It was very desirable that this should be at an early date. The rules were under consideration by all other important bodies, and yet we were held up because of trifling differences from the Board of Trade rules. This sort of thing could not go on, and they had no right to allow it to go on. In conclusion he would mention that there was another committee in existence—a committee on the standardisation of apparatus. The work of this committee did not overlap that of the one they were concerned with. There were a lot of committees, however, and he would suggest the merging of the present Construction Committee into the Board of Trade Consulting Committee. This would have the advantage of retaining the valuable superintendent engineers and other members.

Mr. T. Carlton said that although not a member of the committee, he had attended most of their meetings. A large amount of valuable information had certainly been obtained. The formulæ which had been prepared really followed very closely on the Board of Trade rules, but had a somewhat different appearance owing to the adoption of the $\frac{1}{32}$ in. unit. There were also some differences in scantling. Referring to the paper, in the early part it was said "it seems to be an anomaly, if not something worse, that any Government authority should allow 12 passengers and the captain, officers and crew of a ship to go to sea with boilers which they considered unfit for 13 passengers." He would point out that the Marine Department of the Board of Trade had to carry out the obligations of the Merchant Shipping Act. The definition of a passenger vessel as one carrying more than 12 passengers was almost universally accepted. If not more than 12 passengers were to be carried the owner need not have his vessel surveyed by the Board of Trade. The Board had never suggested that the rules of the registries and others were not useful, but he supposed that if a vessel was changed from one registry to another, the one taking it over would impose their own rules, even if the boat had been quite satisfactory before. The Board of Trade was solely concerned with a good margin of safety for the travelling public and was responsible to the Merchant Shipping Act. In some large passenger ships the conditions were better than those the Board of Trade demanded.

He would say that the various shipping associations, which were directly interested, had never asked the Board of Trade to alter its rules. If there were serious breakdowns and stoppages under the Board rules they would hear of them from the shipping people. This was a matter the Board had always to keep in mind. Breakdowns with passengers on board led to a lot of agitation. The Board of Trade had not failed to recognise the progressive improvements in boiler-making, and their rules worked in that direction. In spite of modern methods, however, there were records of shell plates splitting under hydraulic test, those were plates the material of which had satisfactorily passed the recognised tests. Cracks had also been discovered in plates that had not failed and under strips on boilers, all in spite of tested material. There was no recorded case of a boiler bursting in the British merchant marine, but until cases of the kind he had quoted could be eliminated, extra precautions would be necessary for the safety of passenger ships.

It was in connection with steam pipes that more failures were due than to anything else, and all the failures were with copper pipes. There was only one failure of an iron pipe on record, and that was due to water-hammer. The copper failures were, in his opinion, mainly due to brazing. Credit was due to Mr. Milton for first pointing out this source of danger. The Board of Trade now disapproved of the use of copper for main steam pipes and preferred steel or iron. Mr. Seaton said in his paper that the Board of Trade allowed only 3,000 lb. per square inch on solid-drawn steel pipes as compared with 6,000 lb. for Lloyd's. This was not correct. He was overlooking an allowance of $\frac{1}{8}$ in. thickness in the case of the Lloyd's figure. With pipes $\frac{1}{4}$ in. thick, Lloyd's and the Board of Trade stresses were about the same, and with $\frac{3}{4}$-in. welded pipes Lloyd's figures were about three-quarters of those of the Board.

The committee was of high standing and carried great weight, and he would point out that the Board, in the leaflet already referred to, had come nearer to their recommendations. The modifications to the rules were not yet in their final form. The leaflet was issued owing to the end of the war and urgency with which the construction of passenger ships was being pressed forward. It was quite understood that there was to be a conference to help towards uniformity and to try to bring about a common set of rules.

Mr. J. T. Milton said there was little for him to say as Mr. Morrison had dealt with the whole of the subject so very eloquently. He, however, had been very pleased by what Mr. Carlton said at the end of his speech. The committee had been afraid that the Board of Trade did not propose to recognise or discuss their rules. Although Mr. Carlton was at their meetings the authorities would not allow him to vote. In reference to Mr. Carlton's quotation from the paper in the early part of his speech, he contended that Mr. Seaton's point was a perfectly good one. The anomaly was that a boiler that was good enough for the crew was not good enough for passengers. The Construction Committee was a most admirable one. With Mr. Morrison, he would like to refer to the great assistance received from the superintendent engineers, who knew from life experience what difficulties and failures actually turned up in practice. The Construction Committee corresponded closely with the Technical Committee of Lloyd's. This latter committee had, however, no superintendent engineers among its members, in which it was perhaps inferior to the Construction Committee. The Main Committee of Lloyd's, however, contained shipowners, who were advised by their surveyors, so that the same kind of experience and knowledge was brought in. Mr. Morrison's main point was that a similar committee should be consulted by the Board of Trade. In their criticism of the Board of Trade in connection with the work of the Construction Committee there was no personal reflection on Mr. Carlton. He had been at their meetings and had helped them a lot. What they contended, however, was that the Board should have the technical advice of many engineers and not only of one. It was not for him to say how this could be done. In Lloyd's, however, no rule could be altered without discussion by the Technical Committee and the Board of Trade ought to be able to work on the same system.

Mr. J. Hamilton Gibson said that he also would like to refer to the great assistance the committee had received from the superintendent-engineer members. They were mines of information, and it had been a liberal education to talk to them. As a designer he found himself always dealing with new problems with insufficient data, and it had been a boon to discuss the matters with which the committee were concerned, with those constantly in touch with the effects of practice. In cases of doubt the consensus of opinion of the superintendent engineers had finally always carried the meeting. Liverpool had contributed three of these gentlemen in the persons of the superintendents of the White Star, Elder Dempster and Alfred Holt lines. There had been great enthusiasm in Liverpool for the work of the committee, and there had been many small extra conferences in the various offices by the members. He found it difficult to convey an idea of the amount of work their chairman, Mr. Seaton, had done, he was always weeks ahead of anyone else in suggestions and in providing copies of worked-out tables showing the effect of various proposed rules. He hoped Mr. Seaton would be able to look back on the success of the work of this committee as the crown of his life work in the universal adoption of the proposed rules.

Mr. Sterry B. Freeman said there was a useful way of looking at the matter under discussion to which he would refer. If one felt any doubt about a proposed rule, and to try it, built a model boiler and tested it thoroughly for a number of years, and if the results of that trial were entirely satisfactory, one would be inclined to think the rule was sound. This was the position in which we now found ourselves except that the evidence for the soundness of the rules was enormously stronger. Over 80 per cent. of the marine boilers which had

been built and put into practical service for years past came within the limits of these proposals, and there were only three recorded cases of failure, and these were Dutch boilers made with German steel. He could not understand why the rules could not be accepted by the Board of Trade. Defects of the type spoken of by Mr. Carlton in his speech were not eliminated by thickening up the plates. Indeed, in some ways they became more difficult to detect, as was shown by the Board sending two surveyors to the inspection of boilers having very thick plates.

Mr. J. Foster King said that the discussion had to some extent departed from a consideration of the work of the committee and turned to a debate on the attitude of the Board of Trade. He thought, however, that Mr. Carlton's statement that the Board were going to call a meeting to discuss the matter, disposed of the necessity for dwelling on this aspect of the question further. In view of the present general attitude it was interesting to remember that some years ago he suggested that a boiler code was a simple matter on which one might come to a common all-round agreement, but the reception of the proposal at that time had been distinctly chilly. Things were very different now, and he would say that the Technical Committee of his Registry were advising the adoption of the rules. This move towards uniformity, however, should not be carried too far. In this country at present we seemed to be moving to the standardisation of everything, in view largely, apparently, of the success of the Ford motor car. It was well to remember, however, that despite the wonderful results Mr. Ford had achieved, there still seemed to be room for the Rolls-Royce car. If we were going to standardise all the boiler-making of the world, he trusted freedom for individual development would not be eliminated.

Mr. B. P. Fielden said that he had been asked by the Institute of Marine Engineers to thank Mr. Seaton and the Committee for the valuable work they had done. In connection with the 13 passengers and the 12 passengers, it seemed strange to a marine engineer that what was good enough for 12 passengers and the crew was not good enough for 13 passengers. When one came to adapt a cargo boat for carrying passengers and the Board of Trade insisted on the boilers being strengthened, the assumption appeared to be that the previous 12 passengers and the crew had been sitting on a volcano for years. There was still a matter that required unifying in addition to the rules, and that was in connection with the tests of material. It seemed strange that for a ship built to be classed and also to carry passengers it was necessary to carry out two sets of tests of all material. This was surely a waste. We had done it for years and had got into a groove, but the present was surely a good time for trying to get out of it.

The Chairman, Vice-Admiral Sir Henry Oram, in winding up the discussion, said that the Committee had done an enormous amount of work, which was necessary, but which seemed very great to settle a comparatively simple question. He was interested in the references to Admiralty practice. In the matter of the hydraulic test he might say during 25 years to 30 years in the Navy they had never known a boiler failure due to insufficient scantling or absence of the hydraulic test. In the Admiralty, of course inspection and testing were carried out very thoroughly and at frequent intervals, and corrosion was quickly detected.

Mr. A. E. Seaton, replying to the discussion, said that they had not said a great deal about Admiralty practice in the report, as they still had to consider the Defence of the Realm Act. They were, however, much impressed with Admiralty practice. In the matter of the 12 and 13 passengers the inference was that the Board of Trade must consider these ships, which were working all over the world, as unsafe, because they would not pass them as safe. He was not trying to make a carping criticism, and certainly was not attacking Mr. Carlton, who was an old friend of his. He was sure Mr. Carlton would have been a member of the Committee had he been free to be so. He would be bitterly disappointed if the proposed rules were not accepted and acted on. What they were now anxious for was for the Board of Trade to call a meeting and invite them to it. This would give the Committee a status they would not otherwise have.

Two-Floodable-Compartment Ships.

The next paper to be brought before the meeting was one entitled "Italian Two-Floodable-Compartment Cargo Steamers," by Ing. Salvatore Orlando. It was read by the author. This paper, which we hope to reprint next week, described a standard ship which was developed in Italy in 1917, owing to the heavy losses of the Italian mercantile marine by submarines.

Mr. J. Foster King, opening the discussion, said they were very greatly indebted to Signor Orlando for coming all the way from Italy to present this valuable paper. He (the speaker) had watched the development of this Italian standard ship with great interest, and thought it was one of the most commonsense things that was done in the war. The boats were really a development of the Ansaldo three-island ships, with the engineroom moved aft to give greater safety, in the case of submarine attack, and with the holds divided into smaller compartments. Signor Orlando had suggested in his paper that the two-floodable-compartment ship might remain for the use of the merchant services after the war, but he thought this was asking more than could be achieved. If one obtained a satisfactory one-floodable-compartment ship there would not be much to complain of.

Sir E. Tennyson d'Eyncourt, called upon by the Chairman, said he had not intended to speak, as the matter dealt with was somewhat outside his sphere. He was, however, glad of the opportunity of saying how great had been the assistance received by his department from the Italian naval authorities during the war.

Mr. W. S. Abell said that in this country we had discussed all sorts of devices in connection with the submarine losses, but finally decided that we could not go much beyond the one-floodable-compartment ship. In the smaller type of ship especially it was very difficult to get sufficient bulkheads in to give a two-floodable-compartment construction.

Signor Orlando then briefly replied, and the meeting adjourned until the afternoon.

The Development of Air Ship Construction.

At the afternoon meeting the chair was taken by Admiral Sir Henry Oram, and the first item was the paper by Mr. C. I. R. Campbell, R.C.N.C., on "The Development of Airship Construction." This paper we printed in full on page 469 *ante*.

The discussion of this paper was opened by the reading of a written communication from Lord Weir, who was unable to be present. In it his lordship said that no doubt could now be felt as to the naval and military value, or the commercial value, of airships. The subject, however, bristled with problems of a mathematical and mechanical nature. Experimental work could only be carried out on a very large scale. The figures given in the paper as to the ratio of total lift to disposable lift were significant. For non-rigid airships the disposable lift appeared to range from about 35 per cent. to 45 per cent. of the total lift, and in the case of rigid airships from about 20 per cent. in the case of early airships to about 50 per cent. in more modern ships. The advantages to be gained from airships of increased dimensions were clearly brought out in the paper, and he thought that future developments would be made with large airships of the rigid type. With heavier-than-air craft the disposable lift was about one-third of the total lift, but the ratio was being improved. A certain amount of competition between the two types of aircraft was, Lord Weir thought, inevitable. In commercial application accessory charges were most important, and with large rigid airships the cost of accommodation, gas, &c., were serious items.

The first speaker was Mr. H. G. Williams, who said that the present was the first practical paper on the subject to be presented to the Institution. A previous paper on airships had, however, been read in 1913 by Baron Roenne, who had proposed an airship with a length of 850 ft., a capacity of 3,000,000 cub. ft., and a metallic outer cover. No one had yet had the courage necessary to adopt the design. Mr. Campbell's paper, on the other hand, dealt with facts, and was a remarkable record of progress made. The speaker was in agreement with the author as to the indefiniteness of the limit of economical size between the semi-rigid and rigid types, but did not regard the latter as necessarily superior to semi-rigid airships of the Forlanini type. The disposable lift of the rigid airship R. 29 was given in Table III of the paper as 8·2 tons, whereas that of the large Forlanini airship of approximately the same capacity was about 15 tons. A considerable margin was thus available for strengthening the latter. The Forlanini principle of designing the airships for work at a specific height was important, and might be applied to commercial propositions, as well as to war work. No data was, however, available as to the average height at which airships would have to fly. The speaker thought that a capacity of 3,000,000 cub. ft. was the minimum desirable for airships carrying passengers, or useful loads, across the Atlantic. Such airships were not beyond existing practice, and could be built in existing sheds. Messrs. Armstrong, and doubtless other builders, had designs ready for even larger airships. He had no doubt that commercial airships would pay, but experience had yet to be gained in routine running, and for a period their earning power would be problematical. For this reason Government financial support ought to be obtained.

Sir E. Tennyson d'Eyncourt, K.C.B., the next speaker, said that he had an especial interest in the paper, having been officially responsible at the Admiralty for the naval airships until the end of 1917. The earliest attempt made to supply the Navy with an airship was made in the summer of 1911, but this was not very successful, as the airship (the Mayfly) broke its back on emerging from the shed. This, perhaps, accounted for undue care in the matter of further ships, and airship construction rather retired into the background until the outbreak of war, when it was decided to push on with their design. The new airships were required to be thoroughly reliable, and were intended more to gain experience and for training *personnel*. The earlier rigid airships R. 9 and R. 23 were more for training than for fighting, and they satisfactorily fulfilled their mission. The size was gradually increased, but it was not possible to proceed without trials and experience. The small lifting power of the earlier designs was thus accounted for. German ships examined, the speaker said, showed that our designs had advanced on the same lines as those of the Germans. Continuing his remarks, Sir Eustace said that the advantages of large airships were very great. The law of comparison was applicable to airships, as well as to marine vessels. Airships, however, were more like submarines; there being no wave-making, the resistance did not vary as very high powers of the speed. In practice it was true to say that adverse conditions varied as the square of the dimensions, while advantages varied as the cube. There was a great increase in lift as the size was increased, but cost was another matter. The cost of sheds was an important item, but if airships were moored in the open that item would disappear.

The discussion was continued by Commander Boothby, who said that he, as an airship officer, was glad to notice the general approval of large airships. He also agreed with Sir E. H. Tennyson d'Eyncourt's remarks as to the training afforded by the early airships. A shower of rain would bring them down, the engines were bad, and the pilots encountered many other difficulties, which certainly helped to increase their experience. With regard to the future of airships the problems of handling, and shed accommodation were difficult, but he thought they would be solved in the near future. Airships might start from and land on lakes or other shallow water, and expenses might be reduced in this way. He pleaded for a greater *liaison* between airship constructors and pilots, and pointed out that if the former were actually engaged on airships for about a year they would be much better able to appreciate the difficulties of pilots, and would therefore produce more satisfactory designs.

Mr. E. H. Mitchell, the next speaker, called attention to the tables of particulars of non-rigid, semi-rigid and rigid airships given in the paper. The speeds given for the rigid airships were greater than the others, and this was a most important point.

Not only was the high speed itself an advantage, but this feature would be a valuable aid to the airship in adverse winds or bad weather. All the airships referred to in the paper were for war purposes; it was, however, important to consider their commercial uses. For this purpose they must be reliable. As the speed increased, the airship would become more indifferent to the weather, and an airship with a speed of 80 m.p.h., arranged for mast mooring, would be capable of getting off and landing in any weather. The speaker thought that something was wanting in the progress made with rigid airships during the war. At the end of the war we had no rigid airships equal to those of the Germans, though those now completing showed a very great advance. With regard to the future of commercial flying, Lord Weir had expressed the opinion that there would be competition between airships and heavier-than-air craft. The speaker did not think this would be the case. For short distances airships had no chance, and for long distances over the sea heavier-than-air craft did not come in. They could not provide the necessary degree of comfort, whereas in airships, the accommodation could be at least as comfortable as that afforded by a corridor train. Mr. Williams had said that designs were ready for large passenger-carrying airships, but, at present, the difficulty was to obtain financial support. The cost of travelling would certainly be high, but the high speed was worth paying for. No country had more to gain than our own, from the new method of transit.

The last speaker, Mr. H. B. Pratt, said that the important point of mooring and handling airships had been omitted from the paper. This, he thought, was the crucial question in the development of large rigid airships for passenger carrying. For commercial purposes large sheds and staffs for handling were too expensive, and must be eliminated. The problem, however, was now nearing solution by means of the mooring mast, which enabled an airship to be moored out in the open in any weather. If housed in a shed an airship would have to wait, in stormy weather, until the wind dropped to about 30 m.p.h., but it could be moored to a mast in any wind less than the normal flying speed. Continuing his remarks, the speaker stated that he was not altogether in agreement with the author as to the exact similarity between airship design and naval architecture. As regards general design the two classes of work were closely allied, but in the design of the airship hull, questions such as limiting weight design of girders and struts, &c., the treatment differed greatly from that required for ships or other structures. The strength of airship parts, depended largely upon secondary stresses in the materials. In the design of the lattice girders, for instance, it had been found best to space the bracings in such a manner that they did not cross at the middle points, as, in this way, they were able to obtain greater strength. This point had, he said, been discovered accidently. The design of details such as valves, control gears, &c., involved very high skill in mechanical engineering, and manufacturing problems necessitated experience in repetition work. In the speaker's opinion the best men for this work were those who had been trained in automobile engineering. In connection with the fabric work the designer also required the assistance of the textile technologist. The vast number of small parts required in the manufacture of an airship was not always realised. For a particular airship, the speaker cited as an example, as many as 800 detail drawings were required. The number of entirely different parts used was 21,000, and the actual number of parts was over 2,000,000. The length of fabric used was 30,000 yards and some 2,000,000 rivets had to be closed. With regard to the class of operatives used for the work, labour had to have its say. Female labour had been successfully employed during the war, but he regretted that the trades unions refused to allow women to be employed on this class of work under peace conditions. With regard to non-rigid and semi-rigid airships, the speaker agreed with the author's conclusion that they were successful up to a capacity of about 1,000,000 cub. ft., and that the rigid type then became more economical. As had been remarked by a previous speaker the low performance of the airships R. 9 and R. 23 was due to the fact that they were specially designed for training purposes, and therefore had an inordinately high factor of safety. For handling by means of a crew only partially-trained they had been fitted with swivelling propellers, which enabled them to be drawn down to the ground with less skill in manœuvring. The early classes could have been much improved but for various restrictions imposed and a rigid airship of 1,250,000 cub. ft. capacity, now being built by Messrs. Vickers, would equal or surpass the 2,000,000 cub. ft. capacity airships now in service. In conclusion, he wished to express his appreciation of the cordial co-operation that had existed between private contractors and Admiralty designers in airship work.

Mr. Campbell, who was then called upon to reply, thanked all the speakers on his paper. There had been but little criticism and many valuable suggestions had been thrown out. Time was, however, very limited, and he therefore proposed to submit a detailed reply in writing for publication in the Transactions. A vote of thanks to Mr. Campbell for his paper was then carried by the meeting.

CONCRETE SHIPBUILDING IN THE UNITED STATES.

In the absence of the author, Mr. W. L. Scott's paper on "Concrete Shipbuilding in the United States" was taken as read, and no discussion took place.

SIMPLIFICATION OF MERCHANT SHIP CONSTRUCTION.

The paper by Sir E. Tennyson d'Eyncourt, K.C.B., and Mr. Thomas Graham, B.Sc., entitled "Some Recent Developments Towards a Simplification of Merchant Ship Construction," which had been left over from the morning meeting, was then read in abstract by Mr. Graham. The object of this paper, the first part of which is given on page 503 of this issue, was to place on record the early history and design of, and some of the experiments made in connection with, a type of cargo ship whose inception sprang immediately from the exigencies of war conditions. To fulfil the conditions a design, now commonly referred to as the "straight-frame form," was put forward, and, in building all their national standard ships to this design, the Government have developed the type on a very extensive scale.

The discussion was opened by Mr. James Hamilton, who said that, though he had not intended to open the discussion, he was very much interested in the paper, and had a few questions to ask. He fully agreed that the need, caused by enemy submarines, for a supply of standard vessels justified the authors in trying to produce the simplest form. He did not, however, think the authors would be surprised to find that the square-corner design was not very enthusiastically received by all naval architects. It went against the speaker's own inclinations, and he gave reasons for his objections. He noticed that the diagrams all showed sectional views, which, of course, concealed the unusual shaped contours of water line, which inevitably accompanied the adoption of the rising chine. With regard to the construction, the frames would have to be straightened, and whether this was done cold or after heating in a furnace, they would have to be bevelled. In the matter of fabricated ships very little could be done in this country owing to transport difficulties. In conclusion the speaker remarked that the authors had said a great deal about experiments, but he asked—Where were the ships? Had they been tried and were the square corners successful?

The next speaker was Mr. W. S. Abell, who said he was very pleased to see the paper as it gave an opportunity for discussing war measures with a view to their possible adoption under peace conditions. The two principal questions involved were, in his opinion, fabrication and double-bottom construction. For fabrication they required additional labour and had to provide for transportation of material at a time when the country was depleted of rolling-stock. This question of transport had been a difficulty in connection with the Hog Island yard in the United States, the railway lines in the neighbourhood of the yard having been greatly congested to the detriment of other work. In the economic struggle between shipyards, when prices were cut to the finest limits, the speaker thought that the cheapest construction would result from a certain amount of curvature in the frames. As Mr. Hamilton had said in speaking about straight frames, the latter must be bevelled and straightened. When the bevelling exceeded 10 per cent. from the right angle, they would either have to be rolled with a bevel or furnaced for the operation. With regard to the use of multiple punching machines the speaker thought that a battery of radial drills was even more economical and had the additional advantage that the position of the holes could be more easily varied. Plates could be drilled in batches of four or more at a time. Fabrication had an advantage in that ships could be built without smith work, and it was always desirable to employ the smallest possible number of different trades. He did not agree as to the complete absence of furnace plates; some three or four of such plates had to be used in any case. With regard to the 400-ft. by 52-ft. by 31-ft. ship illustrated in Fig. 11 of the paper, he asked who had approved of this. Was it the Admiralty or Lloyd's? He noticed that the dimensions were those of one of the standard ships. He was not in favour of the lattice-floor construction advocated in the paper. There had been at one time, he knew, a great shortage of plates, and at other times an equal shortage of sections. These conditions, however, were not permanent. The proposition to substitute for the solid plate floor of ordinary construction a series of "N" type girders, and to omit intercostals, could not be very favourably entertained. Another objection was the arrangement of the rivets in groups in the top and bottom members. This would result in more severe stretching under shock than the ordinary arrangement, and the effect of a defective rivet would be worse than in a solid floor. In the Navy the system of bracket floors had gradually disappeared. Most floors of double bottoms were now of the solid-plate type. It therefore appeared that the requirements were best met by a certain proportion of solid-plate floors with two or three open floors in between. The authors' experiments on the resistances of the forms were valuable and interesting. He explained that the comparison between the straight line form and the standard "A" type ship, which showed up to the disadvantage of the latter, was probably due to the fact that the parallel middle portion had been carried too far. The extra resistance was probably due to eddy-making.

Mr. M. E. Denny, the next speaker, regretted that he had not had time to examine the paper more carefully. He had, he said, been associated with the authors in their work, and had been instrumental in transferring the design from paper to practice. The design was suitable for vessels of different types and speeds, including concrete ships. A concrete tug designed with a block coefficient of 0.5, and a value of $\frac{V}{\sqrt{L}}$ of 1, had been designed, and a model tried in the tank had given good results. Mr. Abell's comparisons, the speaker said, he did not think were quite fair as Mr. Abell had been comparing Mr. Graham's form with an improved "A" ship. With regard to the frames it was not possible to do away with a fair amount of work on them; some builders, in any case, preferred to put them in the furnace. In the matter of double-bottom construction he might mention that in the first "N" boat, the double bottom had extended for the whole fore and aft length of the ship, and had been kept above the chine in order to provide some safeguard against the possibility of leakage. The depth of the double bottom was as much as 11 ft. at the forward end of the ship. There had, the speaker continued, been a great deal of work and discussion before the design was adopted, and this only went to show how difficult it was to improve on ordinary methods of construction in an old-established industry in which competition had been so keen. Many suggestions which appeared to be excellent on paper had proved to be less satisfactory than older methods.

Mr. W. Boyd, who followed, said he spoke as a practical shipbuilder, and he thought the authors, and others associated with the work, deserved every credit for having evolved the design. The

work would have been of great service to the nation had the war continued. Many details of the design, he said, had been left to the Wallsend yard to settle, and these caused no difficulty after the work which had been done in London. The ships were certainly not very handsome. The water line, which was not usually given in illustrations, had an unusual form, which was caused by the chine line. The only furnace plates used in the construction of the vessels were four per ship, and these were required at the ends of the chamfer. With regard to the frames, he thought it was best to straighten and bevel them at the same time, after heating in a furnace. Most of the plates used had been punched in multiple-punching machines, and he had found the method most expeditious. The working of the chine bar, the speaker said, had proved troublesome. The moulds could not be made in the loft, but had to be taken off the ship. With regard to the lattice-girder construction dealt with in the paper, he would like to point out that this construction did not apply to the standard ships more than to any other form. Mr. Abell had, he thought, been led astray by this point. In the matter of cost the new ships would compare favourably with ordinary type vessels, but the cost of the ship he had built was actually a little higher. This he considered was due to the fact that it was in the nature of an experimental ship. The men were unaccustomed to the work, and asked higher prices than usual on this account. His work had been to build a sample ship and supply templates to the bridge builders. Both bridge builders and shipbuilders preferred a solid floor, and this had therefore been adopted.

The last speaker, Mr. W. D. McLaren, said he could not agree that the straight-frame form arose out of the war. He had before him specifications which covered the whole field of straight frames. His firm had got out designs for straight-framed vessels, and had had tank experiments made and compared with ordinary forms. They were so convinced by the results that they had decided to lay out a yard for building straight-framed vessels. In the speaker's opinion it was important for the chine to lie in the path of the stream lines in order to reduce eddy-making. In conclusion, he said that the large amount of convincing evidence as to the advantages of this type of vessel would eventually break down all opposition.

At the conclusion of the discussion the chairman said that a communication had been received from Mr. A. C. Ramage, who claimed to have invented the straight-line form of ship early in the war, and mentioned that he had put a proposal forward in May, 1916.

Mr. Graham then replied to the discussion, but owing to lack of time his reply had necessarily to be kept very brief. Mr. Hamilton's remarks, he said, had been based on the square bilge ship. He (Mr. Graham) was not now in sympathy with the square bilge design, which was proposed, at first, as being the simplest to construct. When the chamfered form had been found to be equally economical, the square bilge design had been abandoned. In reply to Mr. Abell he would say that the question of fabrication was entirely an economic one. It was not fair to base conclusions as to procedure, or cost, on war conditions. He would never advise the construction of a single straight-framed ship; the only advantage was to be derived from repetition. Mr. Boyd's experiences were most interesting, and to Mr. Denny he wished to express thanks for Sir Eustace and himself for the work Mr. Denny and his staff had done in transforming the design into an actual ship. Whether the form would be retained under peace conditions depended, Mr. Graham said in conclusion, on the reports received as to the behaviour of the ships now in service.

The meeting then terminated with a vote of thanks to Sir E. H. Tennyson d'Eyncourt and Mr. Graham for their paper.

Corrosion and Erosion of Propellers.

The evening meeting on the 10th inst. opened at 7.30 p.m., Mr. J. T. Milton being in the chair. The first paper to be taken was one entitled "Investigations into the Causes of Corrosion or Erosion of Propellers," by the Hon. Sir Charles A. Parsons and Mr. Stanley S. Cook. In the absence owing to illness of Sir Charles Parsons, the paper was read by Mr. Cook. We reprint it on page 515 of this issue.

Professor H. C. H. Carpenter, who had been associated in some of the work on which the paper was based, was the first speaker. He said that in reference to Fig. 2 in the paper it might be of interest to state the method employed in preparing the cross-sections. It was very necessary in view of the objects of the research that the surfaces and edges should not be deformed in any way when the material was cut, and to prevent this it was covered all over with a fusible metal, which was allowed to freeze. The sections were then cut out. The sections before grinding and polishing were then similarly surrounded with casings of fusible metal. The grinding was done by hand. It would be noted from Fig. 2 that there was considerable variation in the sizes of the crystals in the material, they being divided into zones of large crystals and small. He was afraid he had no explanation of this phenomenon to offer, but the fact did not affect the matter of the paper. In reply to the question whether the effect on the propeller blade was due to corrosion or erosion, he thought the paper clearly showed that any effect due to corrosion was negligible compared with the effect of erosion.

Mr. J. Hamilton Gibson, who had been associated in the work leading up to the paper, said that from the outset Sir Charles Parsons, with almost uncanny prescience, had stated that the cause of the wear or erosion would be found to be cavitation. Various schemes to reproduce cavitation effects were tried and given up until they arrived at last at the beautiful experiments of Sir Charles Parsons and Mr. Cook. The tremendous effect which one might get from water-hammer was known to everyone, but in the light of the information which the paper gave, an earlier experience of his was brought to mind with a new light. He well recalled when on board a fast cruiser on full-power trials he had gone into the gland spaces of the after peak and found the noise was deafening, like that of a million pneumatic riveters. It was now evident that this noise was due to innumerable water-hammers on the propeller blades. Now that the war was over he hoped it might be possible, by fixing a suitable underwater light and camera, to take some photographs showing this cavitation effect on actual ships.

Mr. C. E. Stromeyer said the paper was of great interest and was indeed a discovery. Erosion had been talked about for a very long time, but he thought we now really had an explanation. He understood that the idea was that the repeated blows destroyed the metal at a series of points, which was then washed away. The effect of repeated small blows might deform the edges of a propeller. One could see the effect at any time on the brass plate fixed in a booking office. The effect of the continued small blows of the coins falling on it stretched the top face and it became curved. On the question of photographs he would suggest using a prism revolving at half the speed of the propeller. He thought in this way one would get an effect steady enough for a decent photograph. In connection with the mathematics in Appendix II it appeared to him that if one considered water as incompressible, then the pressure at the apex of the cone would rise to infinity. Actually at about 20,000 atmospheres, which was the modulus of compressibility of water, he thought, however, that the pressure would not rise further, but remain more or less constant. He thought that actually one would get a rebound at the apex and a further rebound, and so on, so that actually one should get a note, a series of waves like a Marconi discharge, instead of the sharp sound apparently heard. By using an elastic fluid, such as air, it might be possible really to hear this note.

Sir John E. Thornycroft thought that the evidence brought forward in the paper was conclusive; but he could hardly agree with Professor Carpenter (if he understood him correctly) that there was no corrosion of propeller blades in any case. It might be true for the case considered, but abroad and in bad water one undoubtedly sometimes got genuine corrosion.

Mr. A. T. Quelch said that as one connected with one of the two largest makers of propellers in the world he was very interested in the paper. It bore out their experience. Some eight or nine years ago they had had trouble with the propellers of the Mauretania and the Luisitania, the pitting extending from 2 in. to 3 in. deep in a very short time. As the foundry had always been the Cinderella of the engineering trades the natural thing, of course, was to blame the metal of the propellers. His firm contended at the time that the trouble was not due to corrosion at all, but was an erosion effect. This was substantiated by the paper. It was quite well known that in any particular class of boat erosion always occurred in the same place in the propeller, it sometimes even showed up a little after the trial trip. In the Mauretania and Luisitania the wing propellers were in rather bad positions, turning inwards and close to the ship. If the corrosion idea had been held to, it would have been a very serious matter for his company. They would have had to replace the propellers two or three times in a season. They had another case in the destroyer Swift. She had four shafts and there was a difficulty in getting the speed and holding it. For the four propellers his firm made 24 propellers in all, and it was very noticeable that as the design was altered the position of the eroded area moved about the face of the propeller.

The paper stated that it was an advantage to machine the blades and remove the slight film of scale. Their experience was entirely opposed to this. They found the less you took off the propeller as originally made the better. He would instance the case of a propeller for the Imperator. It weighed 16 tons and had a surface of 122 sq. ft. It was not easy to get a propeller of this size dead accurate to pitch. If they got within 1 per cent. they considered they were doing well. In the case he was speaking of, however, they were very fortunate, and, taking sections 1 ft. apart, in no case was any section more than ½ per cent. out of pitch, and the errors were all in one direction. In truing-up there was no necessity to remove metal to any extent, and probably the total was only 16 lb. to 20 lb. In practice this propeller proved very successful, and there was very little erosion. After a year in the Atlantic trade with the boat driven hard there was no erosion more than 2 mm. deep. On the 122 sq. ft. of the surface there was a total area of only 0·417 sq. ft. eroded, 0·5 mm. deep. There was 3½ sq. ft. just roughened, and all the rest of the propeller was in the condition it left the foundry. The propellers of this ship were in good positions, but the wing propellers were not quite so well situated as the others. In the starboard wing propeller, out of 122 sq. ft., 2 sq. ft. were eroded 2 mm. deep, ½ sq. ft. was eroded between 0·5 mm. and 2 mm. deep, and 8 sq. ft. were eroded very slightly. The records showed that the least-eroded blade was that which had had the least metal removed. If one had spongy or dirty metal the effect was not the same as erosion. The area would not increase. Erosion did not start from spongy parts. Oxide would wash out, but the area would not grow. If, however, you had oxide in any quantity washed out you would get comet erosion behind it, just as you would with a bolt hole.

Mr. S. S. Cook then replied to the discussion. He said that as Mr. Stromeyer had suggested, the metal after being destroyed by the series of blows was washed out, leaving a small cavity. This would be gradually increased, but as the radius of the cavity became larger the vortex cavities would collapse on a curved surface and so with less relative decrease in radius, so that their effect became less marked. This was why the greatest erosion took place at first. In connection with the mathematics of the paper he would say they only dealt with the case of an incompressible fluid. The mathematics of the compressible case were beyond them. If Mr. Stromeyer, or anyone else could suggest or give any help in that direction it would be very welcome. In connection with Sir John E. Thornycroft's remarks about corrosion, he would point out that the paper only dealt with propellers of good metal on high-speed vessels working in good water. They did not suggest that corrosion never took place. In connection with Mr. Quelch's information he would say that they certainly came to the

conclusion that in general the metal of a propeller was not to blame for the erosion.

The Michell Thrust Block.

The next paper was one dealing with the Michell thrust block, which has been described more than once in our columns. The paper was written by Mr. J. Hamilton Gibson and was read by the author. We hope to reprint the paper in a future issue.

Mr. R. J. Walker opened the discussion. He said the subject of the paper was nowadays of great importance, although it was not until the advent of the geared turbine that the Michell thrust block got a fair chance. One or two early geared-turbine ships were fitted with the old type of multi-block, and gave trouble. Messrs. C. A. Parsons and Co. then experimented with the Michell block, and carried the load on a 2 sq. in. pad up to 3,000 lb. per square inch with success. A development which had taken place in the Michell block since its introduction was the substitution of point pivoting for line pivoting at the back of the pads. He thought the first point-pivoted block was fitted by Messrs. Denny Brothers to the Channel steamer Paris. There was still difference of opinion about the relative advantages of point and line pivoting, as also whether in the case of point pivoting the pivot should be placed at the centre of the block, or to one side of the centre. There was about 8,000,000 h.p. being transmitted on Admiralty ships through blocks of the central-pivot type. The eccentric pivot was so far rather the exception, but he understood that the Admiralty found very little difference between the two. The stream-line photographs in the paper were very interesting, but it appeared to him that these had been prepared by forcing the oil between two glass plates. This would not, he thought, accurately represent what really occurred, since in the actual bearing the oil would be drawn across the pads by the revolution of the collar.

Mr. W. P. Sillince said that the Michell bearing was really an adaption of a journal bearing in which the sides were washed away to carry the body of oil where the pressure was low. In ordinary journal bearings troubles due to heating were frequent owing to the edges of the oil-way gutters being much too normal to the journal surface. If a bearing of this kind tended to run hot, the way to cure it was not to add more oil gutters, but to widen and flatten the gutters already made. He had been shipmate with Michell thrust bearings, and also with thrusts of the multi-collar type, and found the Michell bearing a great relief. It was interesting to think of the converse of the Michell bearing. By inverting the Michell pad you could exclude lubricant from a piston rod, for example, and so keep oil out of the boilers.

Mr. H. T. Newbigin said that he had introduced the Michell bearing into this country fourteen years ago. There had been much opposition to it in the early days, but he had always believed in it. Its design was based on Osborne Reynolds' work on lubrication which was done in 1886. Mr. Michell took the matter up in 1892 and applied it to thrust blocks. Osborne Reyolds' work had been concerned with journal bearings only. Michell had shown the work could be extended to thrusts, and experience had abundantly justified his reasoning. In 1905, when he (the speaker) was trying to introduce the bearing in practice, he had been able to show that even with reciprocating engines there would be a saving of 3 per cent. in coal consumption. He had, however, been unable to get any one to abandon the tried multi-collar type. To try to help the matter, he had brought forward an adaption of the Michell pad for use on an existing multi-collar thrust. Even here, however, he had had no greater success, and this adaption was actually fitted for the first time last year. The introduction of the geared turbine had seen the end of their troubles, but it had taken fourteen years to get recognition.

Mr. Hamilton Gibson, in reply, said that his firm had had a lot of trouble with their first geared-turbine job, fitted with multi-collar thrusts, and that the first he heard of the Michell bearing was that the Channel boat Paris had a single collar thrust that was very satisfactory. He then got in touch with Mr. Newhigin, they got out a Michell design, and had no further trouble. It was the Admiralty who were really responsible for the enormously rapid increase in the use of the Michell bearing. Before the Admiralty took it up, he thought the merchant vessels fitted with it could be counted on one hand. The enormous development of the Admiralty application of the bearing was shown by the fact that the first Admiralty ship fitted with it was run for the first time in August, 1914—an easy date to remember. With regard to the line and central pivoting for the pads, he thought it was not of great importance which was used so long as the pressure was not taken higher than 200 lb. to 300 lb. per square inch. In reference to his stream-line photographs, Mr. Walker was right, of course, and they did not exactly represent what took place on a Michell pad. He thought they gave a good general idea, however. Mr. Sillince had spoken about a converse of the Michell block. He believed Mr. Newbigin already had something of that sort. It took the form of a small pad and had the effect of a well-packed gland. Mr. Newbigin had spoken of it having taken fourteen years to get the value of the bearing recognised. The fact of the matter was that it was invented out of due season. It was not until the advent of the geared turbine that it was really wanted.

This concluded the business of the meeting, which was then adjourned until 11 a.m. the next day, Friday, the 11th inst. We will deal with the proceedings of that day in our issue of next week.

(To be continued.)

AUTOMATIC SIGNALLING ON THE LIVERPOOL OVERHEAD RAILWAY.

Two minor accidents, which attracted little attention at the time of their occurrence, took place on the Liverpool Overhead Railway on January 13 and February 12 last. Although the damage which resulted in both cases was small, the accidents were of technical interest from their bearing on the question of automatic signalling. The Liverpool Overhead Railway, as is generally known, is carried on a steel viaduct the full length of the docks on the Liverpool side of the Mersey. The stations are but short distances apart and a frequent service of trains, from 18 to 20 an hour, is run. The signals on the railway are automatic, except at terminal stations or junctions, where they are worked mechanically. The signals are lowered by solenoids which are energised from a "maker" bar on the track, the circuit being completed when one of the collector-shoes of a train makes connection between the "maker" bar and the conductor rail. When pulled down the signals are maintained in that position by a pawl which is released by the wheel tread of a train depressing a "replacer" bar. When the pawl is released the signal returns to the "danger" position owing to the weight of the spectacle case. Each "maker" bar is placed, say, 200 yards to 300 yards in advance of the signal it operates, and the circuit from the bar is taken through a semaphore switch on the signal or signals immediately behind the train as it is over the "maker" bar, and from this switch is taken to the solenoid of the signal which is to be operated. The presence of the semaphore switch in the circuit prevents the signal behind the train being lowered unless the signal in front has been replaced at "danger." Starting and outer-home signals at stations are also equipped with electrically-operated train stops, which, when a train passes one of the signals at "danger," opens the main circuit and trips the continuous brake.

The scene of the accident of January 13 was Brocklebank Dock Station, at which point the railway is practically straight with a slight falling gradient from south to north, that is in the direction in which the colliding trains were travelling. In connection with this station there is a starting signal about 45 ft. north of the platform, an inner-home about 200 ft. south of the platform and an outer-home 600 ft. south of the inner-home. "Maker" bars are situated 350 ft. and 150 ft. respectively in advance of the starting and inner-home signals. At the time of the accident the 7.13 a.m. down train from Dingle was standing at Brocklebank Station, where it was kept a little longer than usual owing to the starting signal being at "danger." While so standing the train was run into behind by the 7.17 a.m. down train from Dingle. Only minor damage was caused to the stock, but one passenger had ribs broken and several complained of smaller injuries. It was foggy at the time.

It will be evident from what has been said of the signalling system that this accident should have been impossible. The accident happened, however, and the point of interest is to discover, if it can be done, what weakness in the system allowed of this. Clearly the second train should have been stopped at the outer-home signal, which should have stood at "danger" until the first train had cleared the starting signal at Brocklebank Station. Further, the starting signal at Canada Station—the previous station up the line—should not have moved into the "off" position, to allow the second train to leave this station, until this outer-home signal at Brocklebank had moved to "danger." There is, however, an arrangement in use, intended to increase the safety of working during fog, which would appear to make it possible for this latter state of affairs to arise and for the starting signal at Canada to permit the second train to proceed before the previous one had cleared the section. The arrangement referred to is one such that the outer-home signal can be pegged down and the semaphore-arm switch short-circuited. When this has been done the "maker" bar immediately in advance of the inner-home signal (which normally pulls off the starting signal at the station in rear by way of the outer-home semaphore switch) is disconnected, by moving a switch provided for the purpose. The result is that a double section, *e.g.*, between Canada and Brocklebank, is worked as a single section. Lieutenant-Colonel Pringle, in the official report on the inquiry into the accident, states that as the short-circuiting switch is actuated independently of the operation of pegging-down the signal, it is possible for it to be left in the short-circuiting position when the signal is restored to normal working. This would not prevent the working of the signals, but would allow of the starting signal at Canada being pulled off although the outer-home signal for Brocklebank indicated safety.

It was established from the evidence at the inquiry, that the starting signal at Canada was "off" when the second train left, but the position of the outer-home signal for Brocklebank was not definitely determined. Whether this signal was "off" or at "danger" there was, however, some failure of the signal mechanism. Since, if the signal was "off" then the passage of the 7.13 train over the "replacer" bar must have failed to return the signal to "danger," and in any case the continuance of the signal in the "off" position should have prevented the lowering of the starting signal at Canada, unless the short-circuiting system described above had been improperly used. If, on the other hand, the outer-home signal stood at "danger" when the second train passed it, then the train should have been stopped by the action of the automatic train stop alongside it. Tests made very shortly after the accident showed that this automatic stop was not operating.

The general conclusion which Lieutenant-Colonel Pringle draws is that the outer-home signal was standing at "clear" and that the driver of the second train, misled by this, ran past the inner-home signal, which was standing at "danger." This signal was visible from Brocklebank Station platform, and it was apparently established that it was standing at "danger." The main interest of the matter, however, is that in the course of the evidence it was brought out that failures of the "replacer" bar to return a signal to "danger" on the passage of a train had occurred on several occasions, and that on trial the automatic train stop failed to act. Clearly, unless the mechanism of an automatic signalling system is to be reliable the system is worse than useless. The report of the inquiry would appear to suggest inefficient upkeep. Lieutenant-Colonel Pringle does not suggest this, but recommends that if a reliable mechanical "replacer" cannot be obtained that a reversion should be made to the type of apparatus earlier in use on the railway in which the signals were held-off and replaced to "danger" electrically. He also suggests that train stops should be fitted which will ensure that when failures occur the signals shall be in the "safety" and not in the "danger" direction as at present, and that the press switch for allowing drivers to pass signals at "danger," without having the brakes applied, shall be so placed that they cannot be operated from the driver's cab. Further, he proposes that switching arrangements for use in connection with pegging down signals shall be such that if left in the wrong position the bringing of the signals into operation again shall ensure instant detection.

The second accident, which occurred on February 12, did not concern a failure of signal mechanism, but was due to misunderstanding in connection with a code of bell signals which is in use in conjunction with the automatic signalling. As Lieutenant-Colonel Pringle states that "irregularities in working the bell code have developed and it is probable that misunderstandings not infrequently arise," it appears doubtful if the whole of the signalling of the railway is in a thoroughly satisfactory state. In view of the importance and even essential nature of a satisfactory automatic signalling system for a service of the type carried out on the Liverpool Overhead Railway, it is to be hoped that a proper effort will be promptly made to put things on a sound basis. It appears probable that what is requisite is effective maintenance and supervision, rather than any important alteration in the system used.

SOME RECENT DEVELOPMENTS TOWARDS A SIMPLIFICATION OF MERCHANT SHIP CONSTRUCTION.*

By Sir EUSTACE TENNYSON D'EYNCOURT, K.C.B., Vice-President, and THOMAS GRAHAM, B.Sc., Associate-Member.

THE object in the preparation of this paper has been to record in the Transactions of the Institution the early history and design of, and some of the experiments made in connection with, a type of cargo ship whose inception sprang immediately from the exigencies of war conditions.

In the spring of 1917 the depredations wrought by enemy submarines attained to alarming proportions, and it became apparent that in order to combat the menace successfully, the naval campaign against it would have to be supplemented by a steady flow of additional tonnage from the merchant shipbuilding yards.

Such a supplement, however, especially in view of the restriction of output of merchant tonnage during the two previous years, involved comprehensive considerations. Most of the yards, besides being extensively depleted of skilled labour, had assumed heavy obligations with regard to Admiralty construction; and simultaneous demands with a common objective, for more patrols to maintain naval aggression and more merchant ships to maintain adequate supplies, created not only a scientific but an economic problem requiring for its solution a complete revision of policy.

Recognising this, the Government founded a new central organisation with the necessary associated departments to arrange, expedite and control the merchant shipbuilding of the country; and as it was anticipated that so sudden a resumption of mercantile construction on an extensive scale might render it essential to supplement the existing yard resources, it was proposed to obtain assistance from some of the steel-making, bridge-building and structural establishments, other than shipyards.

It was this necessity of widening the basis of production by utilising every possible source of structural activity throughout the country for the building of ships that gave rise to the conception, and eventually the reality, of a "manufactured vessel," and it is to be hoped that at some future time an idea of the great amount of technical and organising work which has been carried out by the Department of the Controller of Merchant Shipbuilding in this connection will be made public.

While the new organisation was being set up, it appeared to the writers that with a complete revision of policy as regards procedure, the time was opportune for introducing a new type of cargo vessel, simple in construction, and which would utilise as far as possible the only available means that existed for accelerating output. These embraced among others the following proposals:—

1. Employment of labour unaccustomed to shipbuilding.

2. A simple construction which would fully avail itself of such labour.

3. A process of obtaining parts of the ship from various sources of supply and subsequently assembling such parts at the building berths.

A design to fulfil these conditions was put forward, and the form evolved has now come to be commonly referred to as the "Straight-frame Form." Somewhat unorthodox in transverse section, this type provoked considerable suspicion when first proposed, but the large amount of investigation and experiment with satisfactory results which have since been devoted to it, has removed much of the early misgiving as far as speed and power are concerned, and in building all their "National" standard ships to this design, the Government have developed the type on a very extensive scale.

The proposal also provided a simple and satisfactory form for the concrete vessels which the Government subsequently laid down; the straight frame-lines facilitating the "shuttering" arrangements in connection with the process of pouring and holding the concrete.

For electric arc welding also, the form possesses many advantages, and in the proposed double-bottom construction, which is fully dealt with in another part of the paper, opportunity is provided for an economical employment of the process.

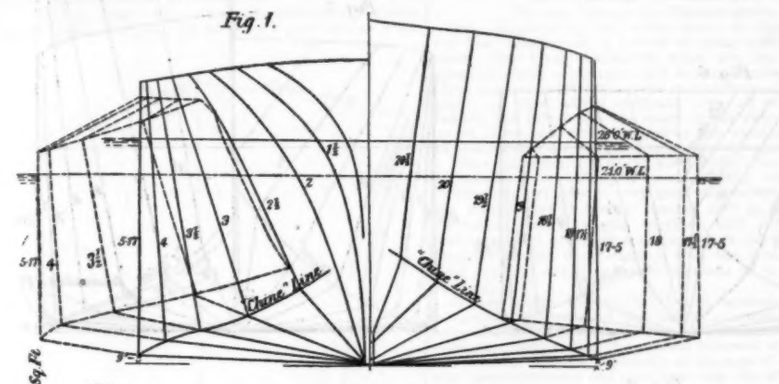
It might be interesting to point out incidentally that one of the incentives which promoted the exploitation of the designs of ships of this kind was the proposal to fit a "bulge" or anti-torpedo protection on the ship's side. The construction, attachment to, and subsequent removal of such an appendage from the hull would have been very simple in a straight-frame form, but for various reasons the bulge was never adopted in the standard vessels.

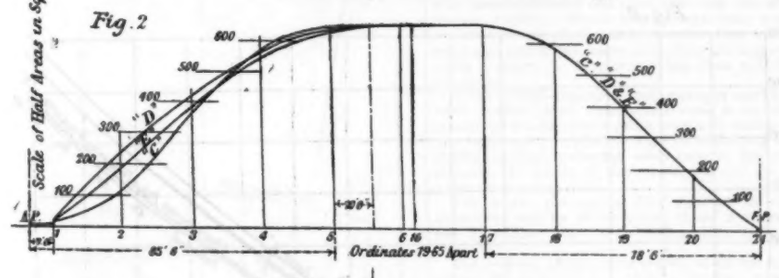
Form.—The salient feature of the straight-frame vessel is that in each transverse section the sides and bottom run in straight lines forming an angular chamfered or rounded bilge. The trace of the angular bilge is termed the "chine" line, which rises gradually towards the forward and after ends to heights depending upon the form and speed of the vessel. The importance of the actual adjustment of the "chine" line has been prominently brought out in practically all the model experiments, and is one of the determining features in the success of a form of this kind. From structural considerations it was proposed to have a constant non-rising "chine," obtained by extending all the side transverse frame lines down to the midship rise of floor, but the resistance entailed with a model of the kind was over 60 per cent. in excess of that obtained for the same form with rising "chine," and the proposal, therefore, was never proceeded with.

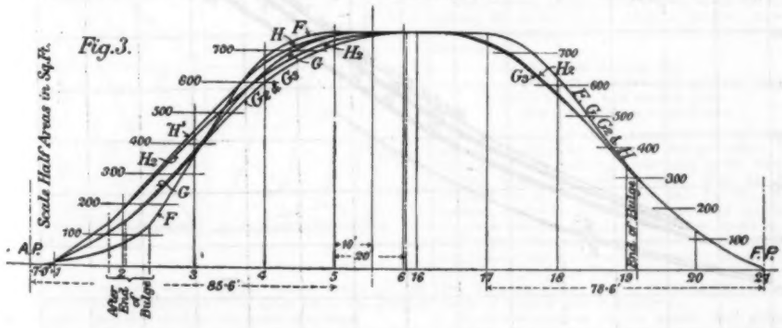
Fig. 1, below, shows the original body plan with bulge protection dotted on, which was got out for a vessel whose naked dimensions are similar to those of the "A" and "B" standard ships, viz., 400 ft. by 52 ft. by 31 ft. to upper deck. The designed speed was only 10 knots, and as it was contemplated to fit bulge protection, the parallel middle body extended for nearly 60 per cent. of the vessel's length, involving a block coefficient of ·8, which rendered the form somewhat unsuitable for comparison with the results of contemporary experiments.

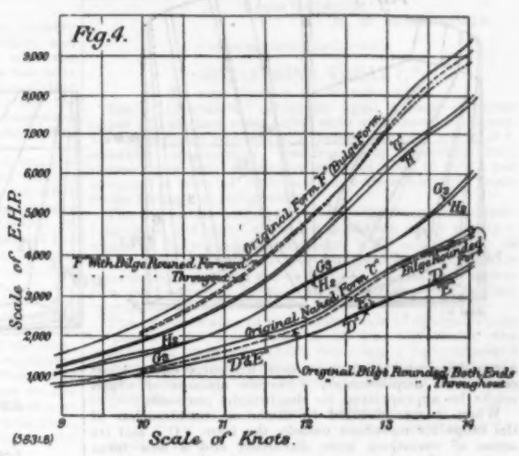
Two comprehensive series of experiments were carried out, however, one series on the naked vessel, and the other on the vessel with the bulge; and the conditions and E.H.P. results of these experiments are illustrated in Figs. 2 to 4, on this page.

The general particulars of the forms comprising the two series are summarised in the Tables below.









Form without Bulge.

Model.	Draught.	Displacement.	Length of Parallel Middle Body.	Length of Entrance.	Length of Run.
	feet.	tons.	feet.	feet.	feet.
"C"	25	11,840	235·8	78·6	85·6
"D"	25	12,010	225·8	78·6	95·6
"E"	25	11,880	225·8	78·6	95·6

Form with Bulge.

Model.	Draught.	Displacement.	Length of Parallel Middle Body.	Length of Entrance.	Length of Run.	Length of Bulge.
	feet.	tons.	feet.	feet.	feet.	feet.
"F"	21	13,630	235·8	78·6	85·6	329
"G"	21	13,705	225·8	78·6	95·6	336
"G_2"	21	13,630	215·8	78·6	105·6	336
"G_3"	21	13,590	196·2	98·2	105·6	336
"H"	21	13,855	225·8	78·6	95·6	340
"H_2"	21	13,665	196·2	98·2	105·6	340

The original form, "C," as already observed, has an extensive parallel middle body reaching so far aft that a defined shoulder appears on the prismatic curve. By taking 10 ft. off the parallel body in this region, as was done in form "D," and running the prismatic curve practically straight to the propeller-post, a reduction of about 17 per cent. in driving power was obtained, although the displacement was augmented by 1½ per cent. As it was feared, however, that being a very full single-screw ship, the full run aft might slightly impair the propeller efficiency, a further modification was made to the form, as shown by "E," giving a slightly hollow prismatic curve at the extreme after end, and the power curve proved practically identical to that for form "D."

* Paper read before the Institution of Naval Architects, April 10, 1919.

Fig. 3, page 503, shows the series of corresponding prismatic curves for the vessel having the bulge protection, and the E.H.P. curves are illustrated along with those for the naked form on Fig. 4, page 503.

For comparative purposes, a series of experiments was made both on the original bulge and non-bulge forms "C" and "F" respectively, having the angular bilge rounded off by a suitable radius, and it was found, as shown on Fig. 4, page 503, that the difference between the rounded and the angular forms within the limits of the speeds tried varied from 2 to 3 per cent. in favour of the rounded forms. A comprehensive series of experiments, made for one of the authors some years ago on bilge keels and their angular bilge equivalents, provide results from which it can be asserted that an angular bilge ship which does not require bilge keels and a similar vessel with rounded bilge having bilge keels will give practically identical results up to, and in some cases beyond, the ordinary speeds associated with cargo ships, and the former vessel will carry about 1 per cent. more displacement, a certain amount of which might be appropriated for deadweight purposes.

When it was decided to abandon consideration of the bulge for merchant vessels, the form "C" and its series of variations were discarded and a new form was evolved to the same dimensions, but having a block coefficient of just under 0·77. Two variations, "K_1" and "K_2," of this new form were tried, having practically the same lengths of "entrance," "run," and "parallel middle body," but the centre of buoyancy in the former was 8 ft. and in the latter 5 ft., forward of the centre between perpendiculars. The draught and displacement in both cases were the same, viz., 24 ft. 10½ in. and 11,360 tons respectively.

The body plans for "K_1" and "K_2" are shown superimposed on each other in Fig. 5, and the E.H.P. curves on Fig. 8, annexed, and it will be noticed that "K_1" gives a better performance at low speeds than "K_2," although the difference is very small. Both curves will compare favourably with the best results obtained for vessels of similar dimensions, designed on orthodox lines, and are better than those derived from the original "A" and "B" standard ship models.

These experiments comprise the investigations made preparatory to the Government proceeding with their proposed programme of "National" and "Fabricated" vessels, and as a final investigation it was decided to have a larger vessel designed on the "Straight-frame" principle, and if this proved satisfactory the new design would in all probability become the parent "National" form. A new form was consequently evolved to the larger dimensions, viz., 411 ft. 6 in. by 55 ft. 6 in. by 28 ft. draught, which, when experimented upon, again demonstrated the possibility of obtaining a good form having transverse straightness of lines in association with the usual curvature fore and aft.

This original "N" form, the body plan of which is reproduced in Fig. 6, above, was, with subsequent modifications, including a forward movement of the centre of buoyancy, adopted for the N-type standard vessels, the actual dimensions of which are now 411 ft. 6 in. by 55 ft. 5½ in. by 38 ft. 1½ in. to upper deck.

An important modification, but one which is primarily of practical significance, has been the chamfering off of the angular bilge, as shown dotted on Fig. 6, above. This was done as a result of the belief expressed by many authorities, that the retention of an absolutely sharp corner would have augmented the cost of maintenance.

Reviewing the results of the few experiments just enumerated, their chief significance consists in a modest corroboration of the conclusions of recent research, viz., that in full cargo vessels the "run" is of considerably greater importance than the "entrance." In other words, a return to the blunt fore-end in association with a fine after-end appears, within limits, to be the directing principle towards an efficient form. From this arises the question as to the most suitable disposition of buoyancy in a fore-and-aft direction, which, in turn, depends upon such practical considerations as the desired arrangement of cargo holds and bunkers. It might be advanced, however, as a general statement, that in vessels having the usual holds forward and aft with machinery between, a longitudinal position of the centre of buoyancy of 1½ per cent. of the vessel's length forward of the centre between perpendiculars would make a good average position. If the vessel were designed with the three main holds in sequence forward and one aft—an arrangement which has many advantages—the position of the centre of buoyancy might be taken as 2 per cent. of the length forward of midships. These general references to the allocation of buoyancy are made because of the significance they bear in relation to the design of single-screw straight-frame vessels. Owing to the necessity of liberal deck space aft and a fine water-line (fine as compared with the deck-line), the ship's side falls in so rapidly that in maintaining straightness of frames right aft, some difficulty may be found in obtaining a full immersed area at the after-end, and consequently the longitudinal position of the centre of buoyancy in this class of vessel falls what might be called "naturally" well forward of the centre between perpendiculars—a tendency which harmonises with the conclusions already stated.

In order to determine the limit beyond which the straight-frame form would not hold out prospects of performance satisfactorily comparable with those of an ordinary vessel, research was continued and extended to vessels of the intermediate type up to 16 knots and to high-power war vessels up to 32 and 40 knots.

With regard to the latter, comparative experiments were made with straight and ordinary forms for a fast light cruiser and a torpedo-boat destroyer, but the series for both classes of vessel produced results from which it is difficult to derive definite conclusions.

In the case of the light cruiser, the difference in power between the two types of form is inappreciable below 20 knots. Above that speed the straight-frame form having angular bilge becomes more resistful to the extent of 2 per cent. at 20 knots, and 8 per cent. at 32 knots. Two per cent. of this extra resistance is due to greater wetted surface, thus leaving 6 per cent. at full speed attributable to residual resistance due to form.

The destroyer forms showed considerably less difference in power. Below 20 knots the difference is again inappreciable. At 20 knots the angular form is 2 per cent., at 30 knots 3 per cent., and at 40 knots 4½ per cent. more resistful than the equivalent ordinary form.

The only inference to be drawn from these results which present so marked a relative difference in performance is that the straight-frame cruiser form was a less appropriate one for that class of vessel than was the destroyer form for its class, due probably to an unsuitable adjustment of "chine" line. But it should be stated that the ordinary form in each of these cases was a highly specialised development, whereas the straight-frame forms got out for comparison, while conforming to the same prismatic curves, may have been inappropriate as regards the vertical allocation of buoyancy, and if so, some proportion of the deficiency may have proceeded from this cause.

Fig. 7, below, illustrates a body plan for an intermediate vessel 500 ft. W.L. (490 B.P.) by 62 ft. by 28 ft. draught, having a mean prismatic coefficient of 0·72 and the centre of buoyancy 2·24 ft. aft of the centre between perpendiculars. Experiments on this form were made under the following conditions:—

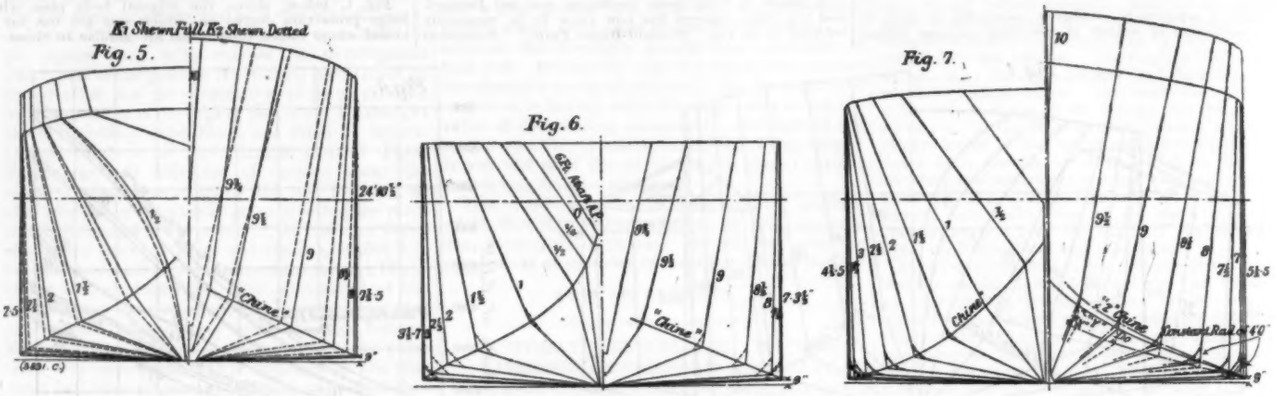
1. Angular bilge with lower "chine" "X."
2. Angular bilge with middle "chine" "Y."
3. Angular bilge with upper "chine" "Z."
4. Chamfered bilge with trace of chamfer following "Z" "chine" line.
5. Rounded bilge of constant radius, trace of bilge following "Z" "chine" line.

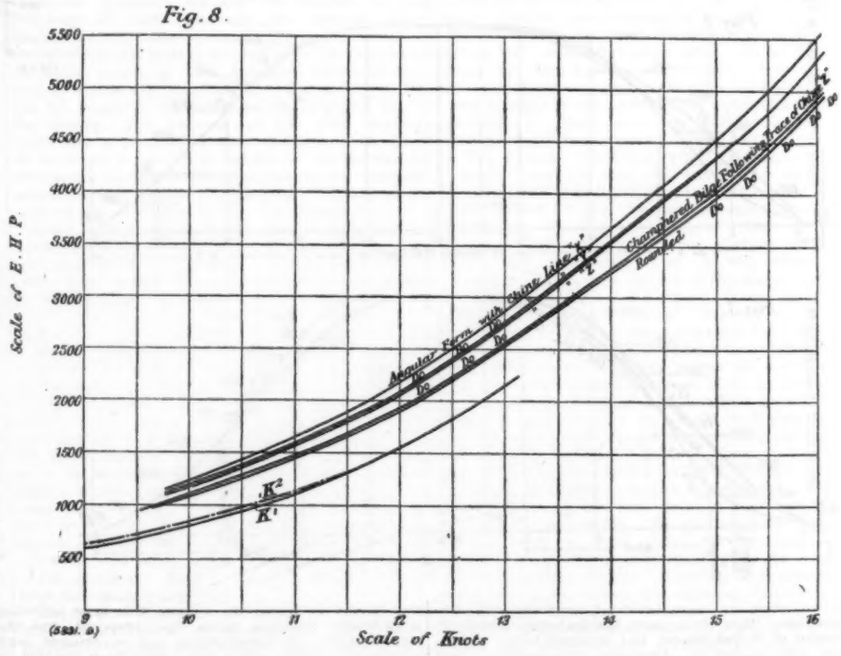
The draught was kept constant at 28 ft. in each case and the corresponding displacements represented by the models were:—

	Tons.
Model with angular bilge "Z" ...	17,475
Model with chamfered bilge ...	17,440
Model with rounded bilge	17,435

The E.H.P. results of these investigations are shown in Fig. 8, above.

With regard to conditions (1), (2) and (3), it will be noticed that a gradual improvement is seen in the performance curve, as the "chine" line forward is raised





from the position "X" to the position "Z," amounting to 6 per cent. of the power; but the difference between the powers obtained from the model having the "chine" at "Y" and the "chine" at "Z" is very small, and a slightly higher elevation still would provide an insignificant reduction of power, but the position "Z" probably represents the most appropriate adjustment of the "chine" for this particular form and speed. Care has to be exercised in not going too high with the "chine," even though a very slight improvement in performance on a trial run might be anticipated, for in a seaway too high a "chine" would at intervals cross the water-line of flotation and involve "impulses" of resistance.

Conditions (4) and (5) provide results almost identical to each other and from 5 per cent. to 6 per cent. better than those obtained from the best condition (3) with angular bilge. This is what might be anticipated owing to the difference in the areas of wetted surface.

Generally speaking, the conclusions arrived at from the experiments referred to and others of a similar kind might be summarised as follows:—

1. Straight-frame cargo vessels of speeds up to 11 knots, having angular bilges, will be from 2 per cent. to 3 per

Fig. 9.

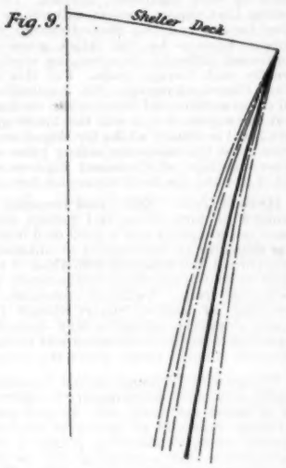
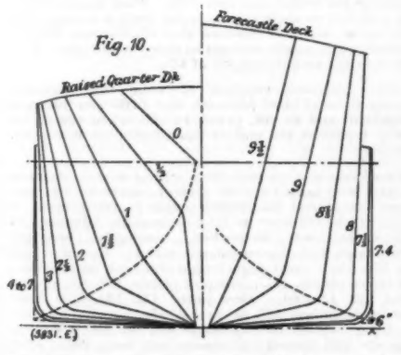


Fig. 10.



cent. more resistful than similar naked forms on the ordinary lines, *i.e.*, forms without bilge keels, the greater resistance being due to their increased skin area.

2. When bilge keels are added to the ordinary form of cargo ship, the 2 per cent. to 3 per cent. advantage in power which it possesses over the angular bilge form is surrendered, and the latter type of form employs the extra surface, which in the ordinary vessel constituted the bilge keel, to enclose volume, and therefore increases the displacement and deadweight accordingly

3. Straight-frame forms having chamfered bilges can be obtained having forms as satisfactory as ordinary forms in cargo vessels up to 11 knots, and above that speed, up to 16 knots, can be applied to intermediate vessels and only require a power of from 1 per cent. to 2 per cent. higher than that required by the equivalent ordinary form.

4. Straight-frame forms having a constant or varying radius at the bilge can be designed to give results as satisfactory as a similar ordinary form both in cargo and intermediate vessels, provided, it would appear, that the rounded bilge forward and aft follows the trace of what would be the most appropriate "chine" in an angular form. This means, for instance, that in cargo vessels the bilge should not be tangential to the sides and a constant rise of floor line, but should have a distinctly rising contour at both ends of the ship.

It should be borne in mind, of course, when assessing the values of these forms, that the differences in power of 1 per cent., 2 per cent. and 3 per cent., referred to in connection with cargo vessels have only a theoretical significance. They imply no more than the everyday differences which occur between ordinary similar forms.

A final point that might be raised in connection with straight-frame forms, and one which is more a matter of seaworthy than of technical importance, is the question of flare or flam forward. The amount of flare which is given to a full cargo ship varies with the requirements of different owners. Fig. 9, above, shows a series of average sections taken at the collision bulkhead from a large number of cargo vessels of the shelter-deck type, and illustrates reasonable extremes as regards flare in this type of ship. The full line shows the corresponding section taken from the form illustrated on Fig. 6, above, and although it could be improved upon, it compares favourably with what is quite an average practice. As a practical suggestion, however, even in a shelter-deck vessel on the straight-frame principle, it would be advisable to add a short forecastle.

(To be continued.)

A CHANGE OF STAFF.

TO THE EDITOR OF ENGINEERING.

SIR,—Engineering and other works in this country are now entering on a period of great difficulty, and unless they bring themselves more into line with the times numbers of concerns will fail to survive the next three years. Inefficient works organisation, out-of-date plant, or poor selling methods, may all account for failure, but before the war many works were hampered by all three, and yet managed to pay their way owing to cheap materials and moderate rates of wages.

The equipment of a works with modern tools and the organisation of efficient manufacturing and selling methods do not present very great difficulties, but what our manufacturers are up against now is the greatly increased rate of wages, together with reduction in working hours, no extra speeding-up on the part of the employees, and the certainty that the limit has not been reached either in wages demands or in reduction of hours.

Higher wages and shorter hours, however, are not altogether the crux of the matter; wages generally were undoubtedly too low before the war, and hours of work too long, taking the general interests of the community into account, especially in the case of employees who conscientiously did their best, but the effect of the honest worker's labour has always been more or less nullified by the slackness of certain other workmen who were not worth the wages they were getting—who were, some of them, in fact, worth less than nothing to any employer.

Given a well-organised and managed works, equipped with modern plant, there would seem to be no difficulty in earning a satisfactory profit even with hours of 44 or 40 per week and a minimum wage of 4*d.* for any reasonably skilled worker, provided—and here is the gist of the matter—the whole of the employees will do their best while they are at work.

The works manager's chief concern in the future, therefore, will be to eliminate those workers who will not do a good day's work and replace them by others who will.

The reasons which cause a man to do his best for the money he earns are too deep to go into in a letter of this kind, but possibly the poet was not far wrong when he wrote:—

> "In the olden days of Art
> Builders wrought with greatest care,
> Each minute and unseen part—
> For the gods see everywhere."

It is certain that most conscientious workers are not actuated solely by hope of advancement or fear of unemployment, but by something more, and it is also certain that dishonest workers, that is, those who wilfully do as little as they can for the money they receive, are to be found in all ranks of people receiving wages or salaries, but it appears that, speaking generally, the higher the state of education and culture of the individual the more conscientiously he will work, and in this respect the Board School education of the last few decades seems largely wanting in inculcation of a sense of honour and self-respect.

It is the opinion of the writer that greater output could be obtained and fewer labour troubles encountered if works could be staffed with employees of a higher social and educational standard than at present. In many works—in most works probably at present—this would be impracticable, but there are many works manufacturing small high-class goods which might well be made by a higher grade of employee, if these could be attracted.

There is no doubt that there are numbers of men not of the artisan class who would much prefer actually to make things in a works rather than work in an office, but the objections they have to earning their living in the works, which are also the objections of the workman himself, are the early hour for starting work, having to walk through the streets in dirty clothes, and having to mix with the rougher type of workman—some of whom are generally to be found in every works. The writer may be mistaken, but he served five years in the shops himself, and believes that the chief objection to factory work is the early hour of starting in the morning; this deters many who would make excellent artisans, and causes those already in factory life to try and get out at the first opportunity. This objection is in process of being removed, there is a great difference between 6 a.m. and 8 a.m., but let us go one step further and suppose the works and office staff all to start at the same time—9 o'clock—and there should be no difficulty in staffing the works throughout with the same class of people, that is in the case of a factory dealing with the lighter and more intricate classes of engineering goods, where overalls were a sufficient protection for ordinary clothes and where proper facilities were provided for washing.

As regards skill the really skilled mechanic has been dying out for many years owing to subdivision of work, and at the present day it would be almost impossible to find mechanics so skilful as the old millwrights of forty or fifty years ago.

The trade unions lay great stress on the term "skilled man," obviously in their own interests, but the war has taught us that there are few mechanical processes which cannot be learnt by any intelligent man or woman in a few weeks' time if they will apply themselves, and the results are equal and sometimes superior to those produced by the "skilled man" who had been at the same work for years. Trouble with workpeople, strikes, restriction of output, scamped work, &c., are in the main chiefly due to ignorance, to a cramped view of life and inability to realise facts outside the worker's own narrow environment; to organise a factory on such lines that a more cultured type of employee will be attracted would seem to be an experiment worth trying.

Yours faithfully,
R. D. SUMMERFIELD.

"SITUATIONS VACANT."

TO THE EDITOR OF ENGINEERING.

SIR,—"Chemist's" letter in April 4 issue of your paper will strike a responsive note with many engineers. To the engineer who has experienced the heavy cost of a scientific engineering training, the advertisements appearing weekly, offering salaries of 150*l.* to 200*l.* per annum for men of high academic qualifications, must cause feelings of indignation.

The big public bodies are among the worst offenders. I know of one case—there are doubtless many others—where a fully-qualified engineer, with membership of the Institutions of Civil and Mechanical Engineers, is retained by a London public body at the same remuneration paid by them to their lowest grades of unskilled labour.

The overcrowding of the profession is of course largely responsible for this state of affairs, but surely the engineering societies, whilst requiring a high standard of attainment from their members, should at least take steps to see that their diploma is correctly valued by employers.

Yours faithfully,
"AN ENGINEER."

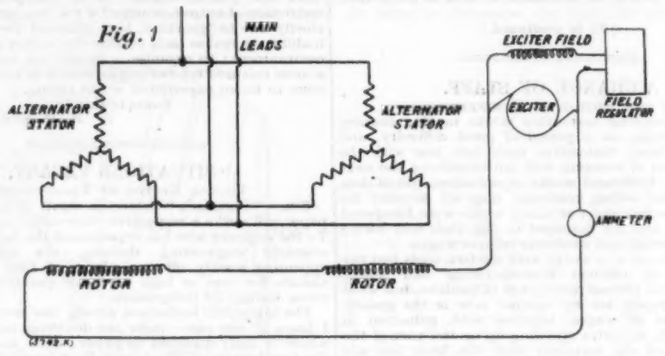
April 4, 1919.

TRIAL TRIP OF THE "SAN FLORENTINO."—The trial trip of the San Florentino, built by Messrs. Swan Hunter and Wigham Richardson, Limited, Wallsend-on-Tyne, for the Eagle Oil Transport Company, Limited, London, which took place on Thursday, the 10th inst., marks another great step forward in the evolution of tank steamer construction. This vessel, built in connection with the Mexican-Eagle oil interests, is designed to carry a deadweight of 18,100 tons and is the largest tank steamer in the world. The previous record for size was held by the San Fraterno and sister ships, which were built for the same company and carried 15,000 tons of oil. The San Florentino is driven by double reduction-geared turbines with oil-fired boilers. Her leading dimensions are 546 ft. in length overall, 68 ft. 7 in. in width with a moulded depth of 42¼ ft. She is built on the Isherwood system of longitudinal framing, under special survey to the highest class of Lloyd's Registry, and conforms to the requirements of the Board of Trade. She has been measured for tonnage to pass through both the Panama Canal and the Suez Canal. The trial trip was most successful, the engines developing 5,000 shaft horse-power with the propeller running at 64 r.p.m., the corresponding speed of the turbines being: High and intermediate pressure, 3,500 per minute, and the low pressure 1,950 per minute. It will be seen from this the advantage which double-reduction gearing gives in being able to use turbines running at the highest speed for their maximum efficiency, and the propeller being designed of the most suitable dimensions for the speed and hull proportions. The San Florentino carried her full load of 18,000 tons deadweight on the trial trip, and maintained a speed of 11·4 knots, which is considered very satisfactory considering the great displacement and very full lines of the vessel. The propelling machinery consists of three turbines working in series and driving the propeller shafting through compound or double-reduction gearing. This turbine machinery has been designed to develop about 4,000 shaft horse-power under ordinary service conditions, and by the adoption of the double gearing the revolutions of the propeller for the given power will never exceed those which would be adopted for a similar single-screw vessel fitted with reciprocating engines. As this two-step system of gearing makes possible speeds of revolutions respectively best suited both to the turbines and the propeller, an overall efficiency has been attained which is probably higher than that of any other type of propelling machinery for this class of vessel. This advance as regards economy has not been obtained by introducing complications or additions to the machinery installation that will call for any increase in the engine-room *personnel*, or will produce any further tax upon the usual staff in supervising the machinery, so that the fuel saving effected really implies a true net gain in the earning capacity of the vessel. The whole of the machinery was built under the supervision of Mr. Thomas McLellan, the superintendent for the company, who has rendered the engine builders valuable assistance in designing the installation to suit the requirements of the trade upon which the vessel is to be engaged.

PLANT EXTENSIONS AT THE KINGSTON-UPON-THAMES ELECTRIC POWER STATION.

SOME interesting extensions of plant which have recently been carried out at the Kingston-upon-Thames Corporation Electric Power Station are illustrated on page 508 and on Plate XXXVII, published this week. The Kingston public supply is single-phase, 77 periods, and 105 volts at consumers' terminals, generation being at 2,100 volts, and consumers being supplied through stepdown transformer sub-stations and pillars. The single-phase generating plant consists of a number of Belliss-Siemens steam sets and one

Fig. 1



500-h.p. two-cycle and one 400 h.p. four-cycle horizontal Diesel sets. The Diesel plant was put to work in September, 1913, and was at that time capable of carrying all the load, so that the steam plant became a stand-by. Recently the demand for power has grown to such an extent that a further increase of plant has been necessary to such amount that the extensions have greater capacity than the original combined steam and Diesel plants.

In these recent extensions, with which we are now concerned, a breakaway has been made from single-phase generation and a three-phase system introduced, with its greater flexibility and convenience for future development. This has, of course, necessitated a link between the three-phase and single-phase systems, and it is this link, in the shape of two 1,000 kw. frequency-changing motor generator sets, which is the main object of this description. Before dealing with these sets, however, we should refer to the new generating plant. This consists of two Brush-Ljungstrom turbo-alternators each capable of developing 1,000 kw. The turbines are of the double-rotation radial-flow type which we have previously described in detail. At the present time the turbines operate with steam at 175 lb. per square inch and 470 deg. F. of superheat, but it is later intended to instal new boilers and raise the steam pressure to 200 lb. per square inch at 588 deg. F. of superheat.

The two alternators of each set, which generate at 3,300 volts and 50 periods, are identical in construction and run at the same speed but in opposite directions. The stator windings are connected in parallel so that the two machines may be considered as a single unit from the point of view of switchgear, &c. The field windings are connected in series and are energised from a single exciter, which is mounted on the end casing of one of the alternators. The arrangement of connections is shown in Fig. 1, annexed. The rotors each consist of a solid steel forging, axial ventilation being used throughout the machine. Mica is used for insulation in both stator and rotor, so that the alternators may run for long periods at high temperature without damaging the insulation. The complete turbo-alternator is carried by its condenser, which is of the surface type and is bolted direct to the flange of the exhaust branch of the turbine. One of the sets is illustrated in Fig. 2 on page 508.

The 1,000 kw. frequency-changer sets consist each of five machines as follows: A single-phase alternator, a three-phase synchronous motor, a starting motor, and two exciters, one for the alternator and the other for the synchronous motor. Two exciters are fitted as the voltage of each synchronous machine has to be controlled by a Tirrell regulator. The single-phase alternator has a capacity of 1,000 kw. at 2,100 volts and 75 periods and power factor 0·8, and a 25 per cent. overload capacity for two hours. The three-phase motor, driven from the turbo-alternator sets, works on a 3,300 volt, 50 period circuit at unity power factor. The starting motor is of the slip-ring type, with liquid starter and operating from the three-phase, 3,300 volt, 50 period circuit. The complete set, which is illustrated in Fig. 3 on page 508, runs at 750 r.p.m. As will be seen, the machines are mounted on a common bed plate. A flexible coupling is fitted between the two exciters and the three main bearings are arranged for forced lubrication. The oil is forced into the bearings by a gear pump driven from the shaft of one of the exciters. No oil cooler is fitted.

The problem of parallel running which had to be faced in connection with these frequency-changer sets was rather complicated, and special attention had to be given to it. The various conditions are as follows:

1. The sets must run in parallel with each other on both the three-phase and single-phase sides.
2. The three-phase motors must run in parallel with the two Ljungstrom sets.
3. The single-phase alternators must run in parallel with the supply provided by the old Diesel and steam sets.
4. The load is to be adjustable between the sets.

An elevation and longitudinal cross-section of the complete frequency-changer set is given in Fig. 4 on Plate XXXVII. The construction of the two synchronous machines is generally the same throughout. Three views of parts of the alternator are given in Figs. 5 to 7, and three views of parts of the motor in Figs. 8 to 10, all on Plate XXXVII. The stator core in each case is supported between two clamping rings keyed into a cast-iron frame. It is built up of best quality iron segments, varnished on both sides and held in position by steel dovetailed keys screwed to inwardly projecting ribs on the cast-iron frame. The coils are wound on formers and completely insulated before being placed in the core. The insulation between turns consists of mica the whole length of the coils. The coils are insulated with mica tubes on the slot portion and oiled linen and mica on the end winding. Before the outer insulation was put on the whole coils were dried under vacuum and then impregnated with a solid compound. The mica tubes were then moulded on under pressure, thus ensuring a solid coil with no air spaces. The winding is so arranged that the voltage between adjacent conductors is a minimum.

The poles and hub of each rotor is a single steel casting, the laminated pole shoes being screwed on after the coils are in position. A heavy amortisseur winding is fitted in the pole face. The field-coils consist of bare copper strips of heavy section wound on edge and assembled under hydraulic pressure. The slip-rings are of gunmetal, carbon brushes in box-type holders being provided in duplicate. Owing to the high speed of the sets very long machines were necessary in order to keep the peripheral velocity within safe limits. It was therefore thought advisable to adopt special means of ensuring a supply of relatively cool air to the centres of the machines. Fan blades are accordingly fitted on the rotor hub with a baffle attached to the end shields, which are solid. In addition to the usual radial vents in the stator core, a series of axial holes have been provided right through the core, thus allowing the air after leaving the stator winding to pass into the core. Holes are also drilled through the rotor hub between the poles to admit additional air to the centre of the machine. To assist when paralleling or adjusting the load, a racking gear is fitted to the motor stator enabling the position of the stator to be adjusted. The stator is carried on rollers mounted on ball bearings, the movement being controlled by a screw gear with a hand wheel. Parts of the arrangement can be seen in Figs. 3 and 4.

As these sets were very urgently required at the time they were built, it was impossible to carry out exhaustive tests on the test bed. The sets were, however, erected at the builders' works and run round for about two hours to see that they were sound. They were then immediately sent away to Kingston and, after erection, were put at once into service and ran continuously day and night without any adjustment. The whole of the plant was designed and constructed by the Brush Electrical Engineering Company, Limited, at their Falcon Works, Loughborough, to the specification of Mr. J. E. Edgcombe. We should add that the single-phase switchgear for use in connection with the sets was manufactured by Messrs. Lucy and Co., of Oxford, and the corresponding three-phase switchgear by Messrs. Crompton and Co., of Chelmsford, to the order of Mr. J. G. Statter. We have to thank Mr. T. A. Kingham, the acting Borough Electrical Engineer of Kingston-upon-Thames, for permission to publish the information on which this article is based.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Home consumers of Cleveland pig-iron are pressing more insistently than ever for April deliveries as higher prices rule next month, and they are keen to make prompt purchases, but they experience great difficulty in finding sellers. Supply of Cleveland pig-iron shows no change, foundry kind being very scarce, and the lower qualities quite plentiful. Forward business on home account is quiet, customers being disinclined to pay the higher rates, but foreign demand for delivery ahead is considerable and growing, and already a good number of contracts have been fixed up with customers abroad. There is a growing feeling that export licences will not be necessary in the near future, and the discontinuance of the system of import licences by the Allies gives satisfaction, but continued difficulty in arranging credits still interferes greatly with foreign trade. For this month's delivery No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.* for home consumption, and for export No. 3 and the lower qualities are 144*s.* and No. 1 is 149*s.*; whilst for May–June delivery makers have fixed the minimum selling price of No. 3 and the lower qualities of Cleveland pig-iron at 140*s.*, and of No. 1 at 144*s.* for both home and foreign trade.

Hematite Iron.—East Coast hematite iron is in steady demand on both home and foreign account, and with home requirements now a good deal more than fully met, less difficulty is experienced in obtaining permission to ship abroad, but financial difficulties in regard to arrangement of credits continues to constitute a serious obstacle to foreign trade. To home customers, Nos. 1, 2 and 3 are 122*s.* 6*d.* and to buyers abroad 172*s.* 6*d.* for this month's delivery, whilst for May–June delivery the latter quotation rules for both home and foreign trade. No. 1 hematite is half a crown above the foregoing quotations.

Foreign Ore.—Though actual business in foreign ore is still very quiet, more inquiry is reported. Consumers, all of whom are fairly well stocked and have yet considerable deliveries to receive in fulfilment of contracts already made, continue to pursue a waiting policy in anticipation that purchasing will be possible on more advantageous terms than now rule. They seem to have been justified in their view, for the freight market now tends easier, and it is reported that charterings, Bilbao–Middlesbrough, might be fixed at round about 18*s.* Best rubio is in the neighbourhood of 45*s.*

Coke.—Adequate supplies of coke are regularly arriving at local blast furnaces, but little new business is reported, and as yet, prices, to rule when the 5*s.* 7*d.* subsidy lapses at the end of this month, are not ascertainable.

Manufactured Iron and Steel.—Producers of finished iron and steel keep busy on current contracts, but new business is almost suspended pending arrangement of prices, which will have to be substantially advanced to meet extra cost. Meanwhile, nominally, principal market rates, to home customers, stand:—Common iron bars, 17*l.* 15*s.*; steel ship, bridge and tank plates, 14*l.*; steel boiler plates, 15*l.*; chequer plates, 15*l.* 10*s.*; steel angles, 13*l.* 12*s.* 6*d.*; steel joists, 13*l.* 12*s.* 6*d.*; steel billets and blooms, 12*l.* 5*s.* to 12*l.* 15*s.*; and steel rails, 13*l.* 10*s.*; whilst to customers abroad the following prices are still named: Common iron bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel angles, 16*l.* 2*s.* 6*d.*; steel joists, 16*l.* 2*s.* 6*d.*; billets and blooms, 13*l.* 10*s.* to 15*l.*; and steel rails, 15*l.* 10*s.*

NEW COASTING STEAMERS.—We read in *The Times* that in the course of a letter to the Secretary of the Chamber of Shipping, dated March 21, Lord Inchcape, who is now abroad, states that he has taken over from the Government the contracts for 96 steamers now under construction of a class suitable for the coasting trade, and that these contracts will be made available to British shipowners in the coasting trade without any profit to himself or to the companies which he represents. He proceeds: "The steamers run from 400 tons to 5,050 tons deadweight, with varying speeds, and shipowners who may be disposed to acquire the contracts should communicate with me. There will also be some 28 vessels of the 'A,' 'B,' 'F' (non-fabricated) and 'N' (fabricated) types taken over from Government since the last lot were disposed of. Particulars of the steamers and the contracts will be placed before shipowners who signify their disposition to entertain their purchase. The allotment of the steamers to owners who may wish to acquire them will be entirely in my own hands, but will be made on as fair a basis as possible. The vessels of the 'A' type are of 8,175 tons deadweight, the 'B' type are of 8,075 tons, the 'F' type of 10,795 tons, and the 'N' type of 10,500 tons deadweight. The 'last lot' of standard vessels referred to consisted of 77 steamers of from 7,000 tons to 11,000 tons, and, as announced in *The Times* of February 15, they were distributed among 23 different British owners."

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—While the steel works in the West of Scotland are busily employed on home contracts, the disturbing element is rife and manufacturers and consumers alike view with considerable concern the increased prices which are imminent when Government subsidies are removed at the end of the month. At the same time it is a recognised fact that the eagerly anticipated expansion of trade can only evolve from free markets and something like normal rates, and these cannot obtain while control endures. Much depends, of course, upon the future cost of pig-iron and scrap. Supplies of these are rather short just now, so that the rolling mills have occasionally to go easy in consequence. Ship and boiler plates are much in demand, and there are also good orders for general engineering work, mainly for the home markets, export still being more of a dead letter than anything else. Not until the iron smelters intimate the new rates for pig-iron will steelmakers be in a position to quote their revised rates for manufactured and semi-manufactured steel, which fact, naturally, prevents any extensive development of business at the moment.

Malleable Iron Trade.—At the malleable iron works, now that the men have resumed their labours, the greatest activity prevails, and every endeavour is being put forth to make up for lost time. Deliveries have been decidedly in arrear and consumers have had to lament steadily decreasing stocks. The necessary "spurt" should soon put things in order again, for there is no lack of work.

Scotch Pig-Iron.—Nothing but uncertainty can be looked for in the pig-iron trade until the withdrawal of the Government subsidies, and although good business continues to be put through, it is all for the most immediate requirements only, and also on home account alone. Both hematite and foundry iron are rather scarce, and it is with difficulty that the available supply can be made to go round. The increased cost of pig-iron, which will come into force as from May 1, is roughly estimated as at anything between 30*s.* and 60*s.* per ton. Some very serious difficulties have to be overcome before the final settlement, and the endeavours being made to establish a uniform set of clauses for a new iron ore charter, with effect both in Scotland and England, is not meeting with all the success that its promoters would desire. As changes are being made, it certainly is advisable that matters should be put on a satisfactory footing.

Glasgow Shipbuilding Enterprise.—Intimation has just been made to the Town Council of Inverkeithing by the Nicholson Steam Tug and Salvage Company, that they are negotiating with a Glasgow combine for the purchase of the Inverkeithing shipyard. As the interest of the prospective purchasers are worldwide, some extensive developments may be looked for in the Forth area.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Business in iron and steel is rather flat for the moment. In all branches, manufacturers hesitate to commit themselves to contract quotations until something more definite is known respecting values of basic material. To what extent the removal of Government subsidies on iron and coke will affect manufactured articles is not definitely known, but the general opinion is that a big advance will be general. In some quarters it is stated that the advance on finished iron and steel will be anything from 4*l.* to 4*l.* 15*s.* per ton. Quotations for pig-iron may, it is stated, advance from 45*s.* to 50*s.* per ton. At the moment, therefore, very few orders are being booked. Complaints are made of the scarcity of sections, bars, sheets and other manufactured material, but this is due rather to the congestion at the mills than to any other cause. The rolling of plates on shipbuilding account is occupying attention to the exclusion of other business. Open-hearth steels are in rather better demand, and there is a steady call for railway material. Toolmakers are very busily engaged supplying the wants of home consumers. Many of the larger firms are well booked up ahead, but an unsatisfactory state of affairs exists in regard to export business, owing to the refusal of the French and Italian Governments to grant exports except under special licence. This is adversely affecting a branch of local industry which before the war relied very largely on Continental requirements. Wire makers, makers of agricultural implement parts, engineers' tools, saws and files, are working full time, with prospect of still greater activity in the future. The cutlery trade is putting its house in order respecting increase of output, by the introduction of up-to-date methods and machinery, and is inviting the attention of engineers in order to meet its special needs in the way of labour-saving devices.

South Yorkshire Coal Trade.—Supplies are reported to be coming forward rather more satisfactorily, and in some cases, by dint of very rigid economy, manufacturing concerns are managing to re-establish their much-depleted stocks. Special attention is also being paid to reserves to tide the iron and steel trades over the Easter set-down at the pits. A substantial tonnage is going away to railway companies and on inland works account, which is facilitated by the suspension of exports *via* the Humber. Full maximum rates are easily obtained. Cobbles and slacks are a very strong market, with practically the whole of the output taken up by contract deliveries. House coal merchants have, during the past week, been able to wipe off a good many arrears, but householders are still pressing for supplies, and the whole of the output is easily absorbed. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—New business has been on a very slow scale during the past week. Most collieries were fully stemmed for loading this side of the holidays, and buyers found it a matter of extreme difficulty to secure even small parcels of either Cardiff large or small steams. Washed, bituminous and dry qualities are also very scarce owing to the pressing demands of inland consumers and the heavy requirements of the Allies. Licences are granted very sparingly, and even to allied destinations it is difficult to get coals released, while for neutrals it is only in exceptional cases that the authorities sanction shipments. At present there are steamers with a carrying capacity of over 40,000 tons, waiting to load for Spain, and a large number of vessels are also waiting their turn for export to allied countries. Some of the steamers waiting to lift cargoes for Spain have been in dock as long as six weeks. There is an ample supply of shipping in the local ports, and it is inevitable that a number of these will be detained over the holidays. Some of the ex-German steamers which have been chartered to load for Italy have arrived, and others are expected. The new working hours of trimmers and tippers came into operation on Monday, and the men will now work two 8-hour shifts a day, against a continuous working day. It is too soon yet to know what effect this change will have, but it is expected that for the start it is bound to have an adverse influence on export. Patent fuel makers are busy and have sufficient orders to carry them over the holidays. Shipments of coke have been much improved of late, though inland business has been restricted by the knowledge that the 5*s.* per ton subsidy granted to coke manufacturers is to terminate at the end of the month. Coke-makers have now decided that the price of coke for inland consumers for the next three months shall be 42*s.* 6*d.* for furnace coke and 55*s.* 6*d.* for foundry coke, which represents an increase of 5*s.* per ton to consumers. Pitwood arrivals have been substantially increased of late. The demand, however, remains brisk, and available supplies have been insufficient to meet the requirements of collieries. Last week over 20,000 loads were imported into Cardiff and Newport. The Pitwood Allocation Committee have decided, in view of the shortage of pitwood, to allocate the whole of the imports themselves, and merchants have been instructed not to sell any pitwood direct but to await instructions from the Allocation Committee.

Newport.—There has been a brisk inquiry for coal, but with large quantities allocated to inland consumers and the demands of the Allies of a pressing character, Monmouthshire large and small steam coals are scarce. Most collieries are fully stemmed for early loading, and buyers have great difficulty in securing even small parcels for the completion of cargoes or bunkers. The tonnage position is very strong, and the number of boats already in dock is greater than at any other time during the past couple of months. In fact, it is certain that a number of boats will be detained over the holidays.

Trade Held Up at Swansea.—For some time past men handling general cargoes at the Swansea Docks have been formulating demands of an unreasonable and exasperating character on the employers. As a matter of fact, it is pointed out by the latter that the workmen have now assumed such a dictatorial attitude that it has become absolutely necessary to take a definite stand upon the matter if the trade of the port was to be continued on a satisfactory basis. Illustrations are given of how the men handicap trade at the docks, and it is suggested that this takes the form of a systematic movement. For example, on one morning men unloading iron ore suddenly stopped work because it was raining, and later in the day they demanded 10*s.* extra per man for waiting, and as there were 30 men engaged in this particular cargo the increase would involve an additional expenditure of 15*l.* Owing to the uncertainty of the sudden extra allowances demanded employers are unable to estimate with any degree of accuracy the cost of loading or unloading a particular cargo. The question was brought to a head on Friday last when work was completely suspended, and so far there is no sign of a resumption. The employers on the one hand are very firm that the issue must be decided once and for all, while the men, too, are holding out for the concession of their claims. As the result of negotiations conducted on the men's behalf a new tariff had been practically agreed upon, but before it could be put into operation additional demands as extra allowances were put forward, culminating in an *impasse*. As a result of the stoppage a number of boats have been held up and others have sailed to other ports, while several vessels on the way to Swansea have been diverted.

Obituary.—Two prominent figures in South Wales business circles have passed away during the past week. Mr. Thomas Roe Thompson, J.P., of Matthew Thompson, shipbrokers, coal exporters and pitwood importers, Cardiff, died on Sunday, and Mr. John Macaulay, for a number of years general manager of the Alexandra (Newport and South Wales) Docks and Railway Company, died on Monday. Mr. Thompson, who was one of the founders of the Barry Docks, was 73 years of age and a native of Sunderland. Mr. Macaulay, who was a native of Edinburgh, was 66 years of age.

NOTICES OF MEETINGS.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 24, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. "The Fullerphone and its Application to Military and Civil Telegraphy," by Major A. C. Fuller, R.E., Associate Member.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, April 25, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W. Lecturette by Mr. John D. North, F.R.Ae.S., F.R.Met.Soc. (of Messrs. Boulton and Paul, Limited), "Commercial Flying."

LONDON TO PARIS FLIGHT.—A remarkable new record has been established by a Royal Air Force pilot for the flight from London to Paris. Starting with despatches from Hendon aerodrome at 3.20 p.m. on Tuesday, the 8th inst., the pilot landed at Paris (Buc) in 1 hour 15 minutes after his departure. The course followed was *via* Dieppe, involving a sea crossing of 70 miles. As the distance from point to point is 215 miles, the average ground speed of the machine was 172 m.p.h. The machine with which the new record was accomplished was a Martinsyde single-seater scout, fitted with a Rolls-Royce "Falcon" Mark III engine of 275 h.p.

PERSIA: MARKET FOR BRICKMAKING MACHINERY.—In calling attention to opportunities for supplying Persia with brickmaking machinery, the United States "Commerce Reports" describe the type of brick and method of manufacture which local industries have been producing for centuries. The most costly mansions of Persia are built of sun-dried bricks, and the flat roofs are generally of mud. In a hot, dry climate, these bricks are durable, as is shown by the fact that some of the towers of Rhei are still standing after 12 centuries. Where great strength is required, the angles are fortified with burnt bricks. Burnt bricks are also used for foundations, chimneys and Persian baths. The burnt bricks used are all produced locally, and so far as is known, none have ever been imported. The kilns, 28 in number, are all located near the south-eastern entrance to the City of Teheran, where there is a supply of light red clay. It is estimated that the total annual output in a normal year is about 30,000,000 bricks. The bricks are all hand-made, and are about 8 in. square and 2 in. thick. After being moulded, the bricks are placed in the sun to dry, after which they are stacked in the kiln, where the burning process lasts three days. They are then removed and sorted into three grades, which sell per 1,000 at 100 krans, 60 krans and 30 krans, respectively (the kran normally exchanges at 4·3*d.*). The price in krans has increased by 50 per cent. in the past four years. Labourers are paid 4 krans to 7 krans per day, according to the nature of the work. On account of the economic situation, building operations are practically at a standstill, and not a single brick was burned in Teheran during 1918. The several kilns still have a supply of bricks on hand, and owners say that none will be made until the demand justifies. It is believed that when the economic condition of the country improves there will be a boom in building operations. Brick-kiln owners say they would be glad to instal machinery if it could be done satisfactorily and profitably. They state it would be necessary to bring machinists from abroad as none are found in Persia. Interest could no doubt be stimulated by sending catalogues and illustrations.

PERSONAL.—Messrs. Peter Brotherhood, Limited, of Peterborough, announce that they have opened a branch office at Commercial Union Buildings, 47, Pilgrim-street, Newcastle-on-Tyne, under the management of Mr. E. Jones, late of the Mirrlees Watson Company, Glasgow, to deal with their business in the North of England.—Mr. Charles Waterhouse, of St. Winifred, Barrington-road, Altrincham, Cheshire, has just retired, after forty years' service, from the position of managing director of Messrs. Luke and Spencer, Broadheath. He still continues his connection with the firm as a director.—Mr. Charles W. Turner has been appointed general manager to the National Benzole Company, Limited. Mr. Turner has had fifteen years' experience in the distribution of oils and other products, and was formerly a member of the Vacuum Oil Company, Limited, Caxton House, S.W. 1.—Major Gerald Hooghwinkel, R.F.A., M.I.E.E., M.I.M.M., of Messrs. Hooghwinkel, Anthony Brown and Partners, consulting engineers, 24, Martin's-lane, Cannon-street, E.C. 4, has recently arrived home from France on demobilisation to take up his consulting practice again after an absence of 4½ years on active service. Captain Anthony Brown is still on General Allenby's staff in Egypt, but hopes to return soon. The firm has recently opened a branch office in Paris and is already extensively interested in reconstruction schemes in France and Belgium.—Mr. Charles W. Hunt has been appointed branch manager of the Associated British Machine Tool Makers, Limited, Manchester and Lancashire area. Mr. Hunt has for many years represented the Selson Engineering Company in the Manchester district. The address of the Manchester branch of the Associated British Machine Tool Makers, Limited, is Lloyd's Bank Buildings, King-street, Manchester.—Messrs. W. Arthur Ker and Co., consulting engineers, factory and works designers, intimate that they have removed to larger offices at 9, West George-street, Glasgow.—Mr. Ewart S. Andrews, B.Sc. (Eng.), has relinquished his appointment as Technical Officer at the Air Board and entered into partnership with Major J. H. Beaumont as Patent Agents and Consulting Engineers at 204–6, Bank Chambers, 329, High Holborn, W.C. 2. Both partners were for many years before the war members of the Examining Staff of H.M. Patent Office.

ELECTRIC PLANT AT THE KINGSTON-UPON-THAMES POWER STATION.

THE BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED, ENGINEERS, LOUGHBOROUGH

(*For Description, see Page* 506.)

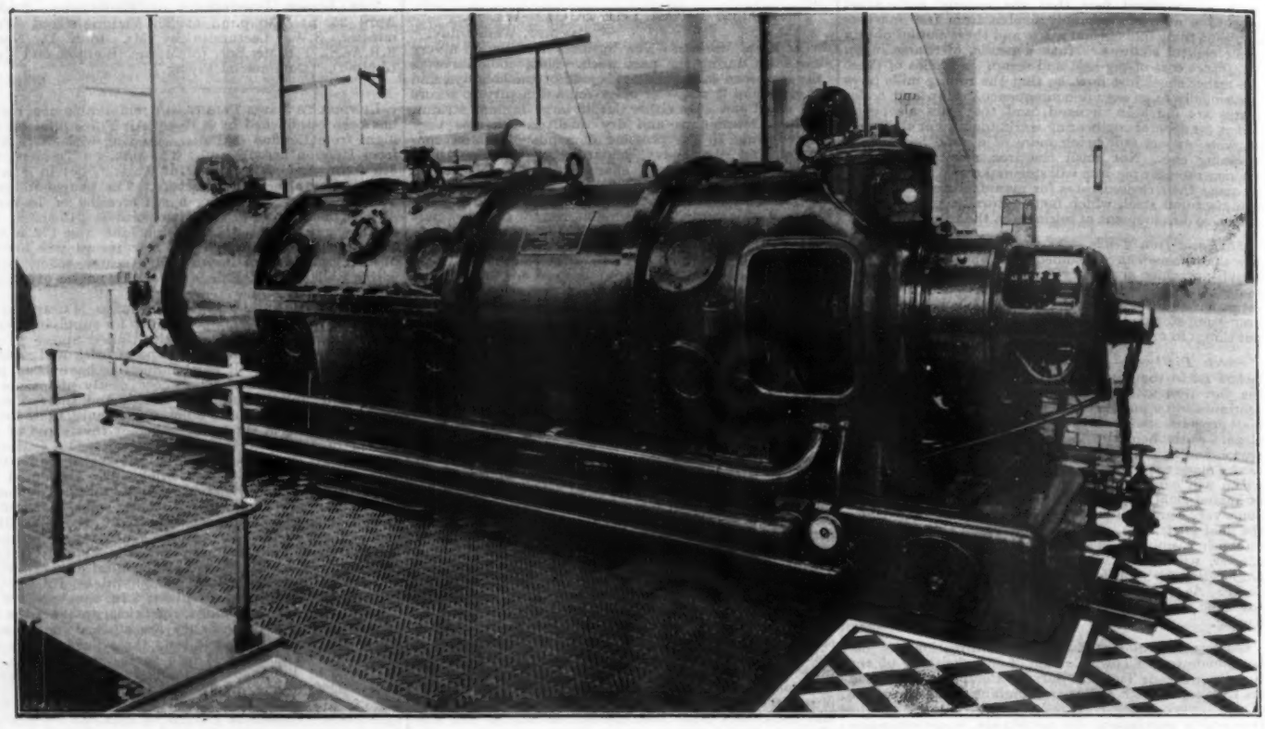


FIG. 2. 1,000-KW. BRUSH–LJUNGSTROM TURBO-ALTERNATOR.

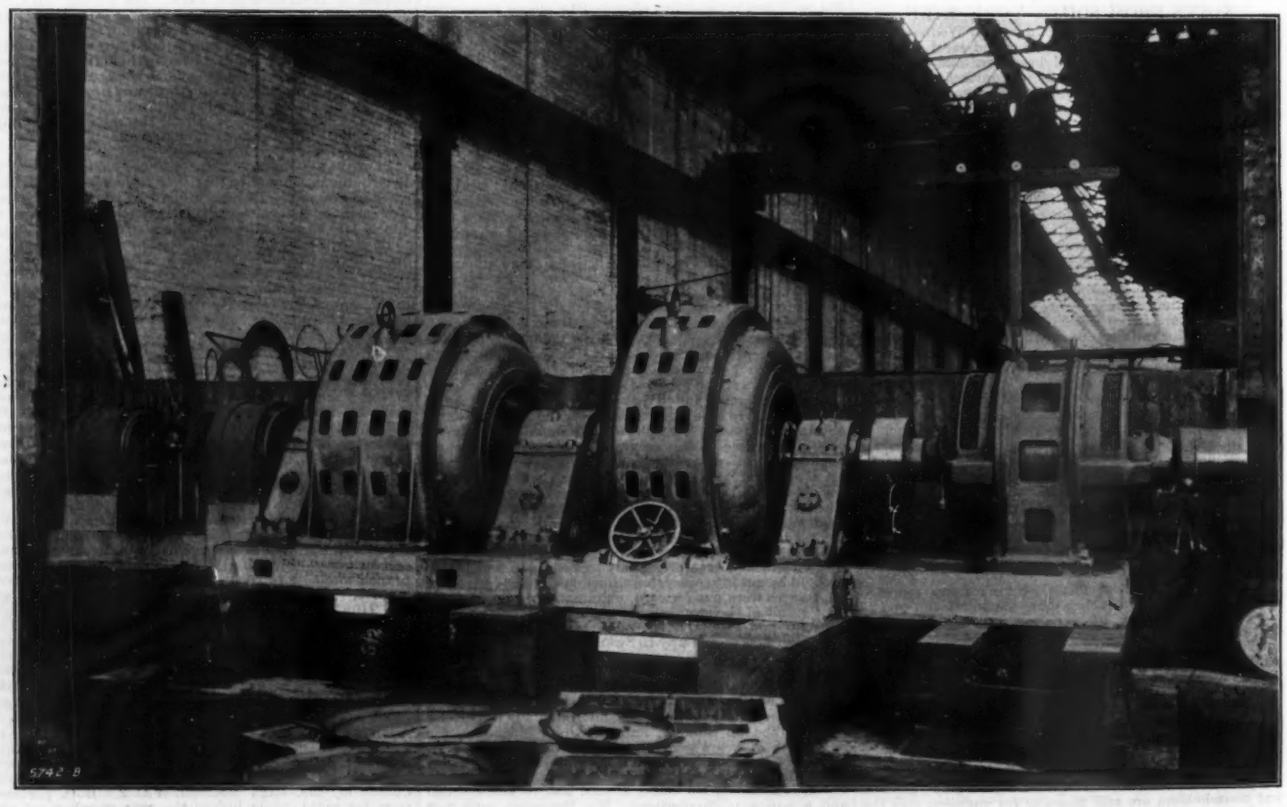


FIG. 3. 1,000-KW. FREQUENCY CHANGER SET.

1,000-KW. MOTOR-GENERATOR SET AT THE KINGSTON-UP

CONSTRUCTED BY THE BRUSH ELECTRICAL ENGINEERING COMPANY, L

(*For Description, see Page* 506.)

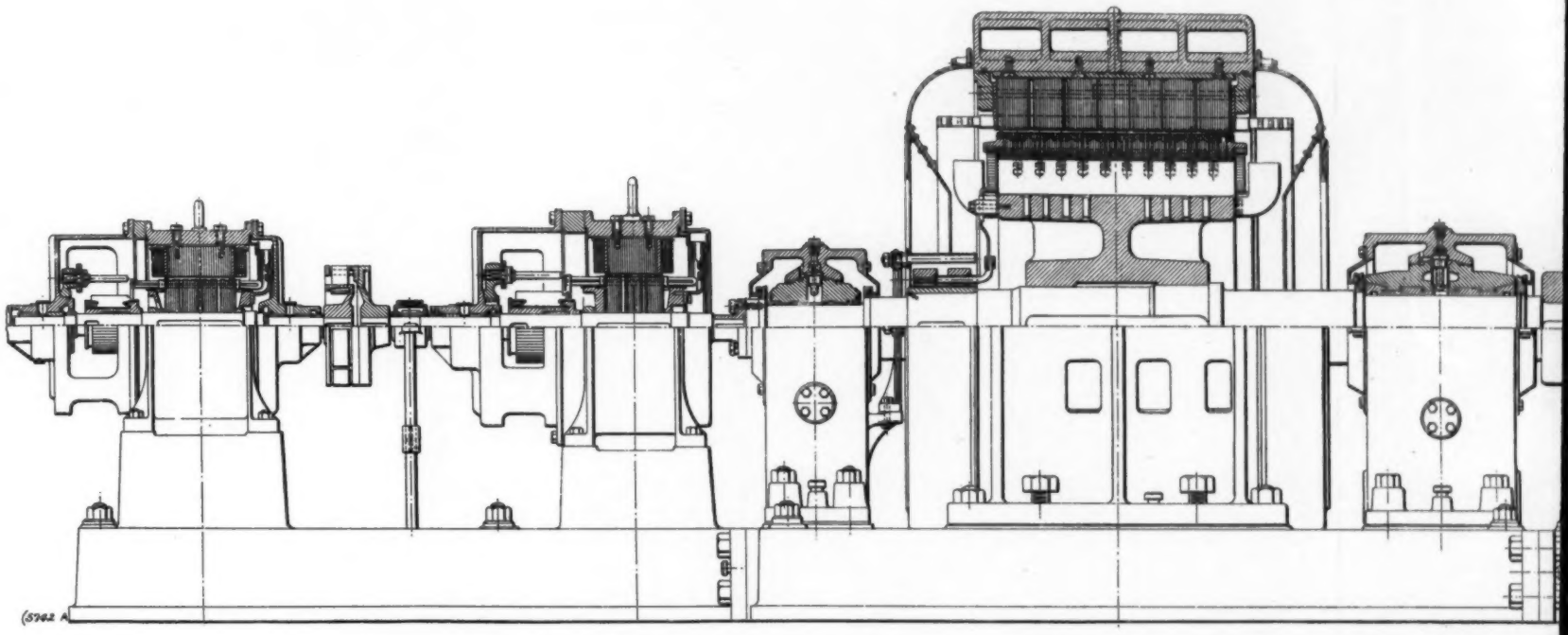


Fig. 4. Elevation and Longitudinal Cross-Section of M

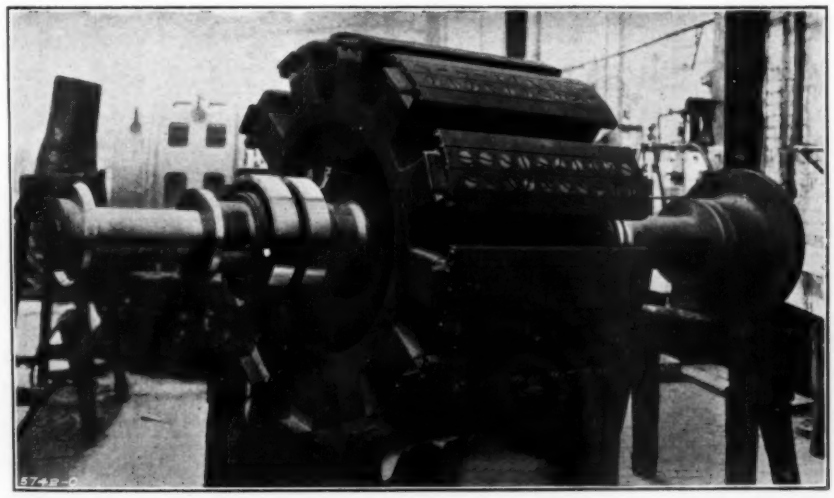


Fig. 5. Alternator Rotor, Unwound.

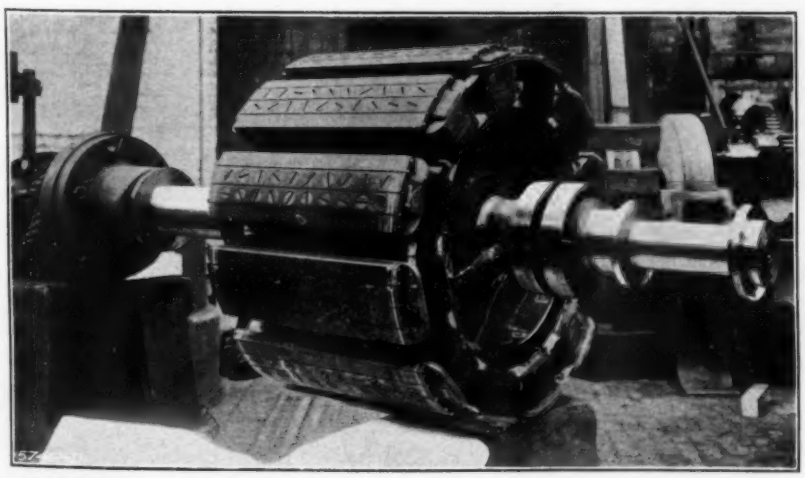


Fig. 6. Alternator Rotor. Completed.

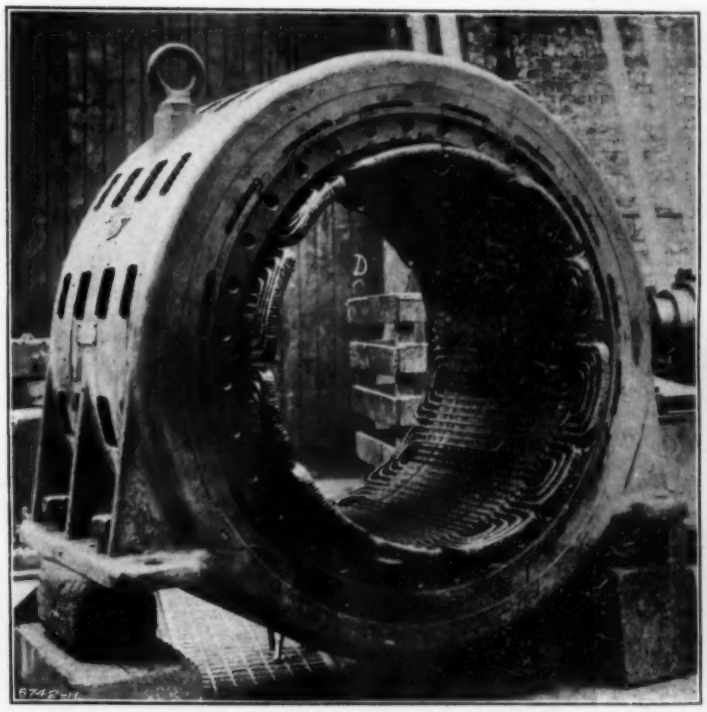


Fig. 7. Alternator Stator.

OTOR-GENERATOR SET AT THE KINGST

CONSTRUCTED BY THE BRUSH ELECTRICAL ENGINEERING C

(*For Description, see*

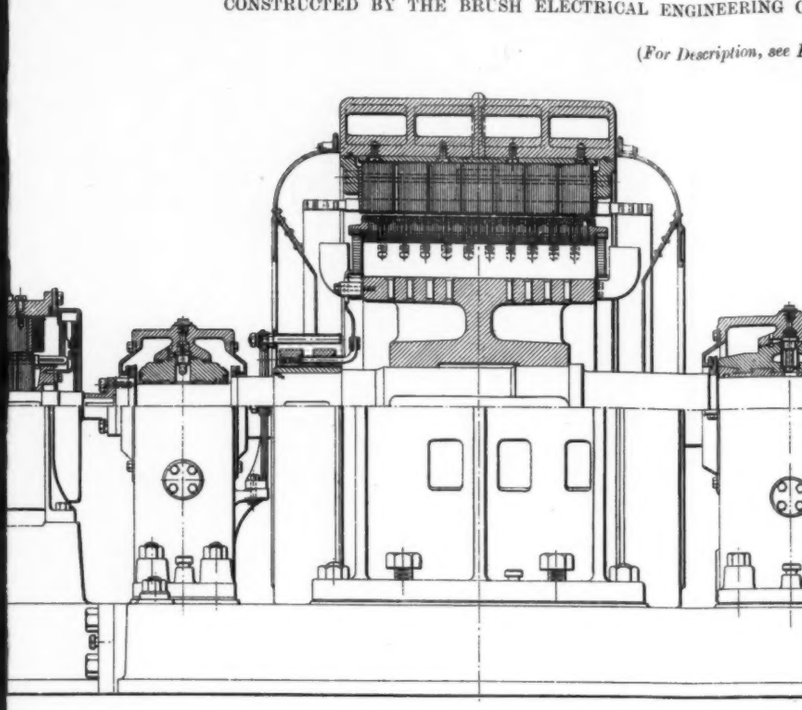


FIG. 4. ELEVATION AND LONGITUDINAL CROSS-S

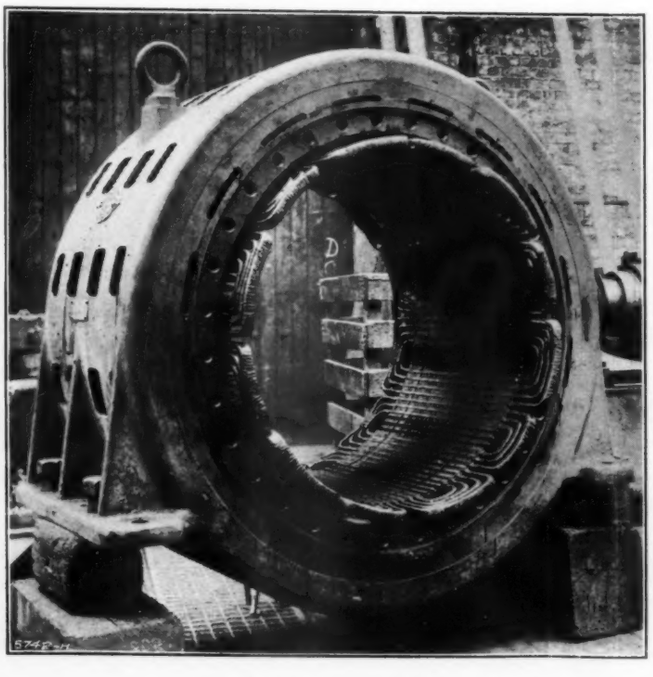
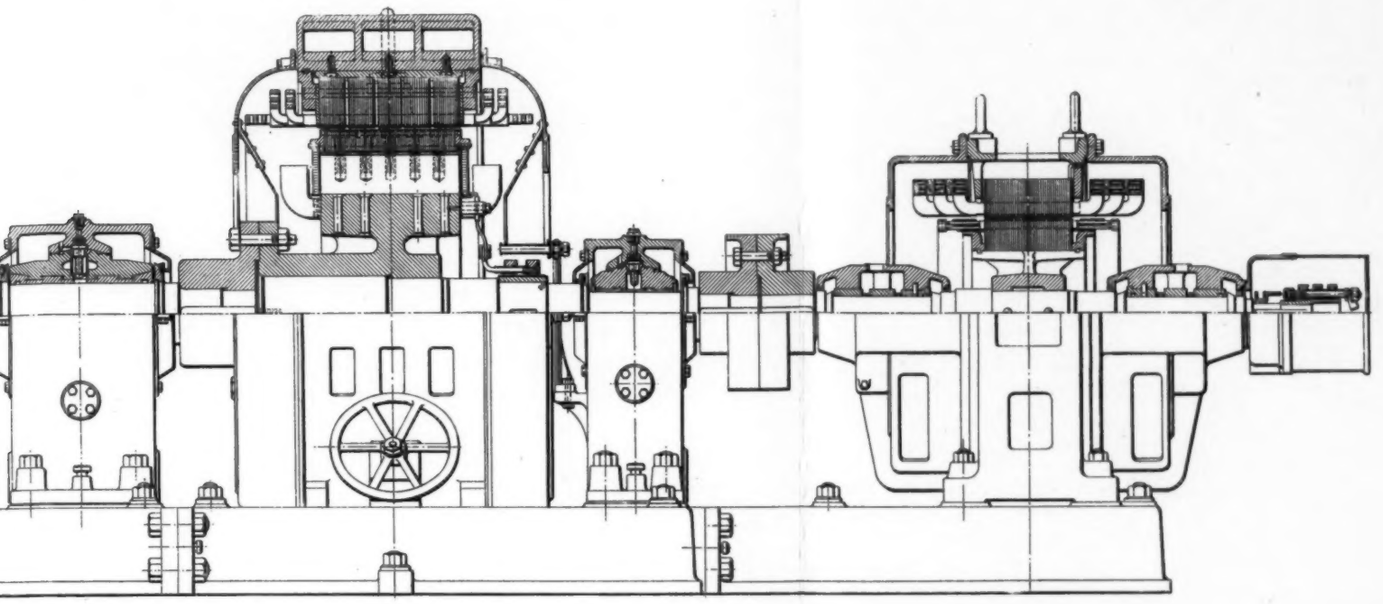


FIG. 7. ALTERNATOR STATOR.

NGSTON-UPON-THAMES ELECTRIC POWER STATION.

NEERING COMPANY, LIMITED, ENGINEERS, LOUGHBOROUGH

ription, see Page 506.)



NAL CROSS-SECTION OF MOTOR GENERATOR SET.

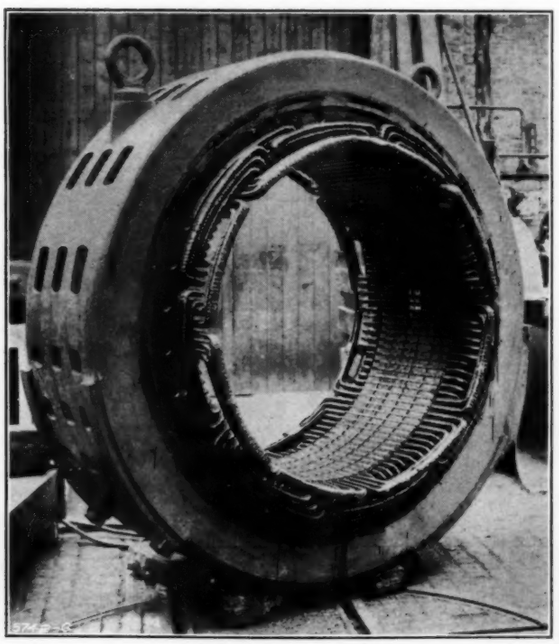


FIG. 8. MOTOR STATOR.

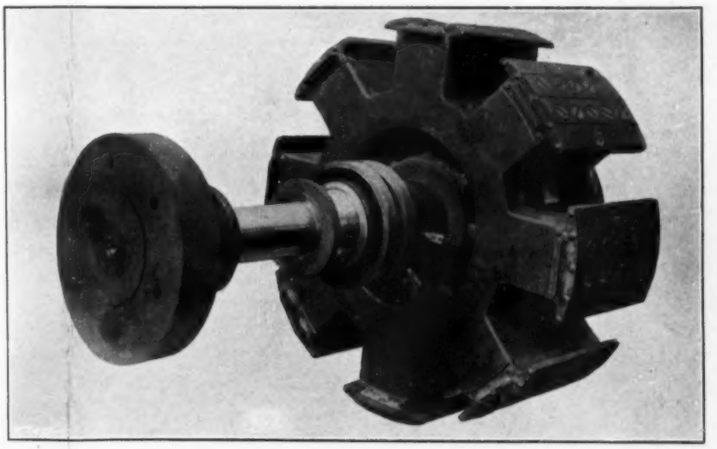


FIG. 9. MOTOR ROTOR, UNWOUND.

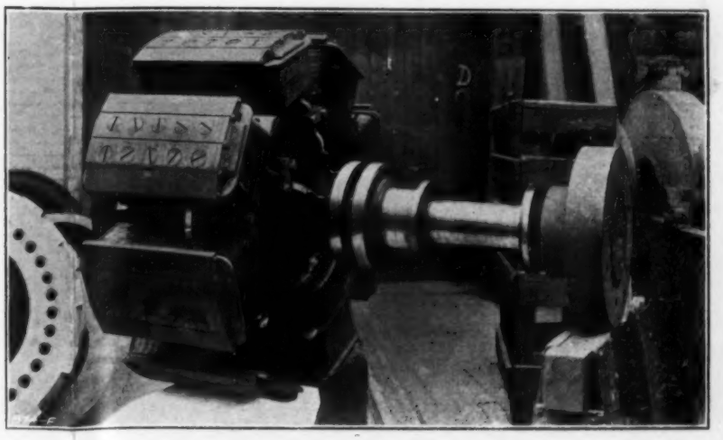


FIG. 10. MOTOR ROTOR, COMPLETED.

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Advertisements intended for insertion in the current week's issue must be delivered not later [illegible] First Post on Thursday. In consequence of the [illegible]sity for going to press early with a portion of the edition, alterations for standing advertise[illegible]nts should be received not later than Monday [illegible]rning.

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Thin paper copies	£2 9 6
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All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8508 GERRARD.

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With a Two-Page Plate of a 1,500-KW. MOTOR-GENERATOR SET AT THE KINGSTON-UPON-THAMES ELECTRIC POWER STATION.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 507.

ENGINEERING.

FRIDAY, APRIL 18, 1919.

THE INFLUENCES OF WAR EXPERIENCE ON WARSHIP DESIGN.

THIS year's session of the Institution of Naval Architects will stand out prominently in the records of the Institution by reason of the historical papers read on warship design, the one by Sir Philip Watts, who was Director of Naval Construction until 1912, and the other by Sir E. H. Tennyson d'Eyncourt, who has held the same post from that date. These papers disclose for the first time, in technical detail, the elements of design of successive ships over a considerable period of years, culminating in vessels just completed and still to be completed, which by reason of their offensive and defensive power, length and speed, far exceed the anticipations of a few years ago. While the process has been one of evolution, there is no doubt that circumstances have encouraged bigger steps in successive types built since the outbreak of war. This is in large measure due to the stress of war requiring that there should be no limit from the monetary standpoint and consequently no check to the risk involved on the part of the designers. In other words, the Director of Naval Construction, instead of having, in popular parlance, to cut his coat to suit his cloth, had a free hand to a greater extent than ever before. There is no doubt, too, that he found stimulation not only from the Board of Admiralty, but from the officers responsible for the command of the Grand Fleet and the several squadrons. This is important because there are many evidences that progress in warship design in the past was handicapped by financial considerations. An admirable example was given by Sir Philip Watts, in his paper, in the illuminative narrative in connection with the experiments in the case of the Inflexible, completed in 1881. She was commanded by Captain (now Lord) Fisher, at the bombardment of Alexandria, and Sir Philip was associated with Captain Fisher, not only in completing and fitting the vessel, but in testing the water chambers to obviate excessive rolling, consequent on her large metacentric height. The result of their association on this ship was the preparation of a design for an all big-gun armament of four pairs of 16-in. 80-ton guns mounted in turrets, all placed on the upper deck, one pair at each extremity of the vessel in the middle line, one pair placed on each broadside *en echelon*, so that four big guns could always be brought to bear on any target right ahead or right astern, or on either bow or on either quarter. On the beam six big guns could always be brought to bear and sometimes eight. This was, indeed, the first all big-gun ship design, but as the scheme involved a displacement of 16,000 tons it was considered inadmissible at that time. It was not for many years—not, indeed, until Lord Fisher was in a position of supreme importance at the Admiralty—that this principle was carried into effect. The highest credit must be given to this distinguished admiral for his continuous and consistent stimulation in connection with warship design. Indeed, it is not too much to say that the progress recently made could not have been achieved but for his guiding and forceful rule at Whitehall.

We do not propose to enter at length upon an examination of the successive steps in the improvement of warships during the war. We would rather deal broadly with some of the important changes in naval tactics which war operations have brought about, and by this means suggest reasons for many of the improvements shown in Sir Eustace d'Eyncourt's paper, as a consequence of a study of those changes in tactics. These were due (1) to the increased range and general efficiency of gunfire, (2) to the increased efficiency of the torpedo, and (3) to the advent of the submarine as a fighting weapon. These three, in association with increased power of aircraft, have greatly affected warship design. The first is the direct result of the improvements that have been made in range-finding and in fire control, which enabled accurate practice to be made at much greater ranges than was previously thought possible. This seems to have been first realised by the Germans, who, with their more efficient instruments, and with the use in the early days of the war of aircraft for range spotting, were able to open fire at much greater range. This, too, was justified not so much by the great power of their guns, but by the fact that these guns had a greater range of elevation, and could therefore be fired at a much greater angle from the horizontal than had ever been done before and than had been adopted in the British service. Practically all the German naval guns, great and small, were ranged for elevation up to 30 deg., whereas the British guns in most cases only elevated to 15 deg., or at the outside to 20 deg. The greater elevation, of course, gave a greatly increased range, roughly about 40 per cent. greater, so that early in the war our guns were in most cases outranged by those of the German ships. Arrangements, however, were very soon made to alter this, so far as our naval ordnance was concerned, but this, in the case of the larger guns, involved serious mechanical and structural alteration, and occupied a very large amount of time.

It will be obvious that as our ships had been designed on the expectation of a 10,000 yards range and a moderate angle of fire the defence was inadequate for the 20,000 yard range and a high trajectory. The danger of plunging shots and the risk of them penetrating the decks became much greater relatively to the risk of penetrating the vertical side armour, to which in pre-war designs attention had been devoted. Frequently shell came down at an angle of 25 deg., or even 30 deg., to the horizontal, and thus after the battle of Jutland it was recognised that the danger of plunging shell penetrating the vitals of a ship demanded increased protection over the magazines. Consequently, as stated in Sir Eustace d'Eyncourt's paper, increased deck protection was arranged for in the new ships, and as far as possible was also provided in the old ships. It will be noted also that, for the same reason, added protection was afforded over the magazines. It will be in the minds of many of our readers that some of the ships, notably the Queen Mary, were sunk in an amazingly short period of time, owing to a plunging shell finding its way into the gun-turret and the flash of the explosive reaching the magazine. This, at all events, is accepted as the explanation of the almost instantaneous sinking of the Queen Mary.

The improvement in the efficiency of the torpedo, and its greatly augmented range, tended also to increase the distance at which naval actions were engaged in, as the opposing ships were naturally anxious to keep beyond the danger zone of the torpedoes of their rivals. From this point of view also it became necessary to increase the range of guns as far as possible, as well as to improve the horizontal protection, so that the torpedo helped to produce those changes which at the same time demanded superior under-water protection against torpedo attacks. Very early in the war the activity of the submarine, as well as the improvement in torpedo range, pointed to the necessity of rendering more effective the under-water protection. Before the war a series of experiments had been conducted and great improvements were made in under-water protection. The efficiency of these improvements was shown when His Majesty's battleship Marlborough was torpedoed at the battle of Jutland, yet still remained a considerable time in the line and continued the action, finally returning to port in safety. The damage she sustained, however, was somewhat serious, and would probably have sunk a ship with anything less in the way of protection.

Immediately after the outbreak of war, Sir Eustace d'Eyncourt put forward proposals for what is now termed "bulge" protection for ships. Experiments

were made, and his ideas proved to be correct, and bulges were fitted to some of the old cruisers of the "Endymion" class, and to the new large monitors mounting heavy guns, and described in the paper read before the Institution of Naval Architects. This protection consisted of a watertight outer compartment full of air and an inner compartment open to the sea, and therefore full of water. It was a long time before any vessel fitted with this arrangement was actually torpedoed, but in the end several vessels with bulges were torpedoed, and survived. A somewhat improved form of bulge, although on the same principle, was also tried and proved efficient; in fact, no bulge ship hit by a torpedo was sunk throughout the whole course of the war. It may be taken, therefore, that this may be accepted in principle as a satisfactory form of underwater protection, and it is likely to be adopted in the future in all vessels. The actual results show that this form of protection is as effective against torpedo attack under water as modern armour is against gun attack above water. It is certainly a great achievement, and although the arrangement adds considerably to the weight of the structure of the ship, and therefore to the displacement, the reduction in speed need not be serious. If the form of the ship is carefully designed the loss of speed is very small indeed with ships of ordinary proportions; no greater loss of speed is entailed beyond that due to the increased displacement consequent on the weight of the bulge. An important benefit of the bulge is that the gases generated by the explosion of the torpedo vent themselves in the air, to a large extent, immediately above the bulge, instead of venting themselves inside the ship, as is necessarily the case when the protection is internal and the explosion gets well into the hull proper.

Both these considerations—the increase in horizontal deck protection against plunging gun-fire, and the under-water protection, add very considerably to the total weight of protection which it is necessary to carry when making a modern capital ship in any way secure against attack, so that the tendency towards larger ships will be accelerated. Deck protection also grows more important as attack from the air becomes more threatening. The trend is towards increased length, and on this point Sir Eustace d'Eyncourt gave some very interesting figures as to the power necessary to drive at a given speed a ship of given displacement. Taking the Renown and Repulse, and comparing them with a destroyer, he pointed out that with not more than four times the horse-power about 24 times the displacement could be driven at the same speed as that of a destroyer, and the Courageous, with about 3¼ times the horse-power of a destroyer, can drive 18 times the displacement at the same speed. These results apply to smooth water; in anything of a head sea, the destroyers are left behind altogether by the big ships. This interesting conclusion gives considerable food for thought.

The cry throughout the war by all those responsible for fighting the ships has been for higher speeds, and in view of the splendid achievements in this connection it is regrettable that the engineer-in-chief of the fleet, Engineer Vice-Admiral G. G. Goodwin, could not be induced to add a contribution to the historic records of naval ship design. Here, again, the results achieved during the war are very largely the product of evolution. There can be no doubt whatever that in the design of naval machinery Sir Henry J. Oram, who was engineer-in-chief till the summer of 1917, showed great courage and scientific ability, and these qualities have been admirably maintained by Sir George Goodwin, his successor and formerly his co-worker. The increases in speed are due to three successive bold moves—the fitting of water-tube boilers and increased steam pressures, the adoption of the steam turbine and the introduction of oil fuel. By these it was possible greatly to increase the power, and at the same time to decrease the weight per unit of power. It would be easy to give figures to establish this contention. As regards the weight of machinery the reduction in the twenty years prior to the war was, in the case of battleships, from 242 lb. per indicated horse-power to 174 lb. per shaft horse-power; to-day it is only 110 lb. In the case of cruisers the twenty years' reduction was from 194 lb. per indicated horse-power to 113 lb. per shaft horse-power, using oil; to-day the result is 75 lb. per shaft horse-power. In the case of destroyers the reduction has been equally remarkable, the figure now being 30 lb. per indicated horse-power. The most significant change during the war was the adoption of the geared turbine. The system had been fitted partly to a destroyer in 1912 and completely to a similar vessel in the following year, while in 1914 a cruiser with geared turbines was on order. The success of these early vessels justified the application of the system in all the new ships soon after the outbreak of war. One of the important gains was the great increase in propeller efficiency. In destroyers, where there are limitations to the increase in size of the propeller, the improvement in propelling efficiency was from about 42 per cent. or 43 per cent. to over 50 per cent. At the same time there was a decrease in steam consumption. In battle cruisers this was brought down to about 10 lb. per shaft horse-power at full power for turbines alone, and for light cruisers to 10½ lb., while for destroyers with twin-screw sets of geared turbines the steam consumption is below 11 lb. This reduction, alike in weight of machinery per unit of power and in the weight of coal required for a given radius of action, greatly assisted the increase in power required to get the high speed demanded by those responsible for fighting the ships. Sir Eustace, in his paper, showed that the Repulse and Renown were fitted with turbine engines of 112,000 h.p., and that their speed was practically 32 knots; while in the case of vessels of the "Courageous" class the power was 90,000 horse-power and the speed 31 knots to 32 knots. Still greater things are being done, however, not only for our own but for allied navies.

Returning to the general question of warship design it may be added that the tendency throughout the war has been to add very much to the various fittings; *i.e.*, such additions as depth charges, increase in the number of searchlights, heavier bridges, increased wireless communication, range-finders, &c., and in many cases additional fuel, have all added greatly to the weights to be carried. Practically all our fighting ships larger than destroyers are now adapted to carry aircraft and have arrangements to admit of aeroplanes flying off and, in some cases, flying on to the decks. This is a departure which has only been made during the last eighteen months. So important has this feature of naval tactics become that there has also been a steady increase in the number of special ships fitted and designed to carry large numbers of aircraft, and this feature will probably be further developed in the future. Incidentally, all these increases have added considerably to the cost of the ships, apart from the question of increased cost for labour and material; but in view of the fact that the issue of the great world war depended very largely on naval tactics and on success at sea, whether in preventing the invasion of the country or in the safe convoy of our troops overseas and of cargo ships with food and other supplies, no one will doubt that the expenditure in all cases has been thoroughly justified.

OIL FROM CANNEL COAL AND ALLIED MATERIALS.

In February, 1918, the Institution of Petroleum Technologists appointed a committee on "The Production of Oil from Cannel Coal and Allied Minerals"—to obtain evidence in respect of the quantity of cannel coal and allied minerals available in Great Britain as a source of motor spirit, fuel oil and other products, and to formulate a scheme for the utilisation of such supplies. The committee drew up an interim report on July 27, 1918, which was approved by the Institution on July 31, and copies of the report were at once presented to the War Cabinet and to various Government Departments. The War Cabinet acknowledged receipt on August 1, intimating that the matter was under consideration. On August 6 the committee requested that a joint deputation from the committee and the Institution should be received by the War Cabinet; the Secretary of the Cabinet suggested that the Ministry of Munitions should be communicated with as to a deputation. The Ministry of Munitions was therefore asked to fix a date for the reception of a small deputation; to this communication no reply was ever received. There followed, however, on August 20, a letter from the Prime Minister informing the committee that the papers they had sent in on August 1 had been referred to Mr. Walter Long's Petroleum Executive Committee which should directly be communicated with. This, we see from the final report submitted by the committee to the Institution of Petroleum Technologists, and now published by the latter body, was the end of the official correspondence in the matter. The committee felt some doubt, it is stated, as to the proper Government Department authorised to deal with the subject.

The interim report had urged several recommendations: (1) That the War Cabinet be invited to lay down a definite policy for the guidance of the department as to the relative national value and importance at the present time of oil and coal, and the provision of the necessary labour, raw materials and transport; (2) the Government should afford all necessary facilities to those prepared to find the capital and to take the risk for the erection at suitable centres of plant for the treatment on a commercial basis of the material known to exist; (3) that an experimental station be established forthwith so that retorts of any design provisionally approved of by the Institution of Petroleum Technologists could be erected and tried out, and material be tested as to its character, oil yield and residual value; (4) that such experimental station should be maintained by and at the expense of the Government; or alternatively (5) that the Government should afford all necessary and reasonable facilities to the Institution of Petroleum Technologists for the erection of a testing station of their own.

The wide scope of these recommendations may help to explain the premature termination of the official correspondence and, up to the present, of the whole matter so far as the Government is concerned. The industrial and economical importance of the problem will not be questioned. Much mined coal, good and poor, is not brought up the bank, or is thrown on the spoil heaps or returned to the underground workings. If the substitution of the shovel for the fork, so strongly demanded by the miners, were made obligatory, still more material would, the interim report pointed out, be sent up and wasted. If, however, the recommendations of the committee were adopted and retorts were erected, the increased supply of material could be utilised, and the colliery owner would be enabled to pay the miner for the extra tonnage brought to bank. As the outcome of the issue of the interim report the Midland Coal Products Company, Limited, has been formed with a capital of 100,000*l.*, all subscribed. The site acquired, it is pointed out, is in the centre of the Midland coalfield, flanked by the Great Northern, the Great Central and the Midland Railways, and adjacent to three shafts which bring up a representative series of materials for all experimental purposes, true cannel as well as inferior cannel, half-inch top hards and soft coking coal. The company intends to test in its experimental and research station not only local materials, but materials from any part of the world. The boilers and electric plants of adjacent colliery workings afford the means of commercially testing and utilising all residues, smokeless fuel, non-condensable gas or gas obtained from residues through the medium of a producer. In addition to the erection of large works the company further intends to assist in the establishment of works and to co-operate with colliery owners and others in any part of the world. There is no Government assistance, as we have stated already, and the company is not interested in any particular type of retort or process. An immense amount of work, it is said, has been done by the technical advisers of the committee and others; different types of retorts and producers have been studied; retortable materials have been investigated, and the present and possible colliery outputs have been gone into, and all the data have been collected for the production of a report showing the possibility of establishing the industry on a sound commercial basis. The chairman of the committee is Captain R. W. Barnett,

M.P., the vice-chairman Admiral Sir Esmond Slade, and the technical advisers are Mr. E. H. Cunningham-Craig (geological), Dr. F. Mollwo Perkin (retorting), Dr. A. E. Dunstan and Mr. A. G. V. Berry (chemical), and Mr. J. Arthur Greene (mineral and supplies); the last mentioned is also honorary secretary of the committee, which has its offices in Trafalgar Building, 1, Charing Cross, S.W. 1.

It is a very ambitious project. We have not particularly referred to chemical by-products, but their utilisation, of course, forms part of the scheme. The Institution of Petroleum Technologists has resolved to place the information obtained by the committee at the disposal of the Midland Coal Products Company subject to the conditions that the experience gained should be available to all colliery owners in the country desiring of developing the industry, and that retorts of any design provisionally approved by the Institution should be considered with a view to their trial and adoption. Particular attention is thus directed to retorts. The coal problem is the "burning" question of the day in more than one respect, and the retort question technically the most burning of all. It has not of late been a neglected problem, however; the war has emphasised its importance though it temporarily limited the scope of experimental investigation. Projects of the kind mentioned are not unique. The development of the Department of Chemical Technology of the Imperial College of Science and Technology, to mention one recent, somewhat cognate scheme, aims in the first instance at the extension of the Fuel Section, partly in co-operation with the Skinningrove Iron Company and other works. Similar institutions exist elsewhere. The objects of a training college for chemical engineers differ, of course, from those of an undertaking for industrial research. Sooner or later, however, the State will take up the fuel problem, and whether it will develop a nucleus of the college type or a commercial undertaking should depend upon the efficiency and adaptability of the concern in question.

SPECTRUM ANALYSIS AND ATOMIC STRUCTURE.

BEFORE opening his fifth lecture on "Spectrum Analysis and its Application to Atomic Structure," at the Royal Institution on Saturday, April 5, Sir J. J. Thomson, O.M., P.R.S., speaking with manifest emotion, said that lecturing in this place and on spectrum analysis, it was fitting for him to refer to the great loss science had sustained by the death of Sir William Crookes, one of the great leaders in the study of the subject they were discussing. Very nearly sixty years ago Sir W. Crookes had made one of the most striking applications of spectrum analysis which had led to the discovery of thallium, and working on uninterruptedly, until a few weeks ago, he had put forth a series of researches unsurpassed almost both as regards experimental skill and the importance of the results. Sir Joseph would only mention the discovery of the radiometer, one of the romances of science in the sense that a clue, which had appeared very remote, had been followed up until it led to the striking effects which Sir William had so often exhibited in this place. Sir Joseph further mentioned the study of the electric discharge through high vacua and the Crookes "dark space," and the important series of researches on the spectra of the rare earths when bombarded by kathode rays. Sir William had started as many new subjects as almost any physicist working in this country for the last century. He had that instinct which all great scientists must possess of being able to select the proper subject, and the power, too, of saying the first word on the subject, and it was the first word which counted a great deal in all subjects of physical investigation. The Royal Institution, whose audience he had delighted many times, and of which he had been Honorary Secretary for a considerable number of years, owed him great service. Sir W. Crookes was one who had increased and upheld the prestige of British science.

Turning to his subject, Sir Joseph stated that in the last lecture he had explained what was meant by the quantum theory with respect to their problem: whenever radiant energy was transferred into some other form of potential or kinetic energy, the transformation was not continuous, but took place by definite units, and when we transformed energy of other forms into energy of radiation, the energy disappeared by units, which represented multiples of the frequency of the radiation produced. He now wished to describe a remarkable application of that theory to the subject of spectrum analysis, which we owed to Dr. N. Bohr. Bohr imagined a hydrogen atom, the single electron of which described a circular orbit round a central positive charge, and he assumed the force due to that charge to vary according to the inverse square law. On that law, Sir Joseph considered, there was nothing to fix the orbit; given suitable velocity, the orbits might be of any radius, and the whole space round the positive charge might be filled with possible paths of the electron. The phenomenon of the light given out by hydrogen showed that this could not be so; such a complexity of paths should result in a continuous spectrum, and not in a series of lines. Sir Joseph himself had accounted for the necessary differentiation by substituting another law for the inverse square law. Bohr, he said, selected certain orbits by applying a certain principle which closely resembled the quantum principle, but was not really that principle itself. Bohr suggested that the only possible orbits were those in which the energy of the electron was bearing a definite ratio to the speed of rotation, and was a definite multiple of the frequency. That condition separated out an infinite number of orbits at definite distances apart. The energy was $\frac{1}{2} m r^2 w^2$, and Bohr's condition, that the ratio of the energy of the electron to its angular velocity was an integral multiple of a definite unit, gave the equation:

$$\tfrac{1}{2} m r^2 w^2 = h p w / 2\pi,$$

where h was Planck's constant, p an integer, and $w/2\pi$ the frequency of the rotation if w represented the angular velocity. When we divided the equation by w, the equation changed into $m r^2 w = h p/\pi$; in other words, all the possible orbits must have a moment of momentum represented by $h p / \pi$, and this moment increased by jumps, as p was first 1, then 2, &c. Combining this relation with the consideration that the electron was held in equilibrium by the attractive force of the positive electricity which was counterbalanced by the centrifugal force, we had $m w^2 r = E e/r^2$, or $m w^2 r^3 = Ee$. From these two equations we could find the values of both r and w, and the different p gave with the different r a series of radial positions for the electrons at separate distances from each other, as on Sir Joseph's own view. But there was this difference between the two views: Sir Joseph's radial distances were proportional to $1/p$ and proceeded in harmonical progression, whilst Bohr's distances increased with the square of p. Thus Bohr had one position at distance 1 from the centre, the next at distance $2^2 = 4$, &c., and the position corresponding to a line of the 30th order would be at distance 900, so that the higher members of the series might be of more than atomic dimensions.

There was another principal consideration. Bohr's electron was assumed to describe orbits in definite times, but not to give out any radiations except when the electron was changing from one steady orbit to another. Innocent as that assumption might appear to be, Sir Joseph wished to point out, it involved great consequences from the dynamic point of view. On the electro-magnetic theory of light radiation-waves corresponded to the propagation of electric and magnetic forces. But if the orbital motion of Bohr's electron were not to produce radiation, it could not even produce magnetic force. For, if it did, that magnetic force would depend upon the distance and the direction of the moving electron, and the force exerted by a particular electron at any point would be different from the force it would exert when it was at the opposite end of a diameter; thus the magnetic force at any point corresponding to a certain value of p would vary periodically. According to Maxwell's theory, however, the periodic variation of magnetic force must necessarily be accompanied by something which was indistinguishable from radiation. Thus, if we wished to retain the fundamental idea of the electro-magnetic theory, we should have to suppose that, somehow or other, the electron moving in its orbit did not give rise to any magnetic force.

Granting with Dr. Bohr, however, that radiation was not produced by the electron while describing a steady orbit, we had to see how he conceived radiations to arise. Bohr suggested that radiation occurred when the electron tumbled from one of its steady orbits into another, and that a quantum law held there: that the energy which the electron acquired in falling from one orbit to the other was transformed into radiation according to a quantum law. Bohr's $h\nu$, then, was equal to the difference in the energy between the two orbits. In this way Bohr obtained an expression of the form $N\left(\frac{1}{p^2} - \frac{1}{q^2}\right)$, and not only the form of his equation was right, but the constant N was correct, and the lines of the Balmer series of hydrogen were reproduced with extraordinary accuracy. From the arithmetical point of view Bohr's theory was therefore unexceptional, and it had led to a great advance in spectroscopy—it was one of the great merits of theories that they led to extended investigations. But the theory was open to considerable difficulty from the physical point of view, and one of the difficulties was this: the frequency which corresponded to the lines did not correspond to the frequency of any electron in that system. Bohr's frequency merely depended upon the energy which was transferred to it by dropping from one orbit to another. There was nothing in Bohr's atom in its normal state which needed to vibrate with the frequency of one of its lines. Sir Joseph referred in this connection to the sharpness of the lines of some absorption spectra. These cold vapour lines belonging to the principal series were so sharply defined that it was difficult to get away from the idea that they must have something to do with resonance. But the strong absorption could hardly take place in a system which had no period to correspond to it. Sir Joseph was not at all sure, in fact, what it was that Bohr supposed to vibrate, whether it was the electron itself or something associated with it.

Continuing Professor Thomson repeated that the higher members of the hydrogen series of Bohr would correspond to electrons of very large orbits. Now these extreme lines were not, as a rule, seen in spectrum tubes, but were of frequent occurrence in stellar nebulæ, because, Dr. Bohr said, there was no room for their orbits in our tubes, whilst the very small gas pressure in the nebulæ left the electrons room for large orbits without interfering with one another. Lately, however, Merton and Nicholson had obtained these lines even at very considerable pressure, more than 30 mm. of mercury, provided that pressure were produced by helium. The effect of the neutral gases in bringing out lines in the ultra-violet had been observed by Liveing and Dewar years ago, and Merton and Nicholson had extended this research. It was difficult, moreover, to understand on Bohr's view why the region corresponding to the limit of the spectrum should not always appear bright. If the lines were excited by electrons falling in, and the higher lines were due to electrons tumbling in from great distances, at high velocity, the case would be that of the charged atom of an ionised gas moving about among many electrons; most of these electrons should produce the limit lines with great brightness; but that was not so. In both theories, however, Bohr's and Sir Joseph's, light emission would be due to the falling in of an electron into an atom which had been deprived of an electron.

Professor Thomson proceeded to show some experiments in which this falling-in was artificially prolonged, so to say, cases where atoms had been exposed to forces driving out electrons and the return of the electrons had been hampered in some way; they might, for instance, have difficulty in finding their way back into a solid substance, or the centres might be situated at great distances. Sir Joseph first exhibited a collection of glass tubes containing various sulphides capable of phosphorescing in different colours. The tubes were exposed to the bright light of the lantern,

which was then turned out; some of the atoms were probably ionised, the light driving out the electrons and leaving the atoms positively charged; the glow which afterwards marked the return of the electrons to the atoms persisted for an appreciable time. This could also be shown with gases, when they were filled into spherical glass bulbs, and the bulbs were placed inside a primary coil and exposed to the high tension; the glow was not so brilliant and persistent as with the solid sulphides, yet it remained quite distinct with some gases. As regards the artificial acceleration or retardation of the return of the electrons, Sir Joseph referred to the experiments shown on other occasions by Sir James Dewar, who froze or "stored" the phosphorescence by immersing the substance in liquid air after exposing it to the radiation. Sir Joseph himself demonstrated the opposite effect; he hurried the phosphorescence up, hastening its disappearance, but concentrating it in a short space of time and making it momentarily brighter. For this purpose Sir Joseph used a discharge tube containing some calcium sulphide, mixed with manganese, in a kind of shovel; the shovel was attached to a narrower glass tube sliding in the outer tube and was fixed there air-tight by the aid of some wax. When the sulphide was bombarded by kathode rays, it phosphoresced in a beautiful green light; the luminosity soon faded. The tube was then heated sufficiently to melt the wax and to allow Sir Joseph to pull out the inner tube with the shovel; the sulphide was dark, but when the shovel was heated in a Bunsen burner the luminosity broke out again. Another tube shown by Sir Joseph contained neon, a little mercury and a few small glass bulbs (fixed) to enhance the friction between the glass, the mercury and the neon on shaking the tube; the ruddy light of neon was at once seen when the tube was shaken.

Coming back to the Bohr atom, Sir Joseph remarked that an alternative to the difficulty mentioned was that there should be two kinds of light: (1) A kind of light represented by Maxwell's equations, yet not producing the effects we associated with light, except in a Pickwickian sense; and (2) a kind of light produced by the falling-in of the electrons. The assumption of two kinds of light involved obvious difficulties, of course. The great point about the Bohr theory was the remarkable agreement between his values and the frequencies observed. The lecturer was not inclined to lay too much stress on that agreement, however. In the Bohr atom all the electrons were rotating, and the equilibrium was between the central attraction and the centrifugal force. In Sir Joseph's atom the electrons were at rest and occupied positions at which the electric force vanished; the electric force, which he assumed, did not vary with the inverse square of the distance inside the atom, and when not obeying that law, it was accompanied by a magnetic force. The magnetic force determined the vibrations which gave rise to the radiations, and if we assumed a simple relation—further explained, Sir Joseph mentioned, in this month's issue of The Philosophical Magazine—between the electric and magnetic forces, his views led to Planck's law and gave a physical concept for the quantum theory in the sense that the frequency of light was proportional to the work which had to be done in order to remove the electron from the atom. How was that to be understood? Supposing the hydrogen atom had been deprived of its electron. Falling back into one of the equilibrium positions, the electron would twist round the line of electric force and, while twisting, would radiate and give out energy, the energy being that which the electron had acquired by falling-in from the outside. This assumption as to the connection between the magnetic and the electric force now made that energy proportional to the frequency of vibration in that place; thus the energy transformed into radiation would be proportional to the frequency, and we got a kind of quantum law. Then take the converse case, the transformation of radiant energy into the energy of separating the electron from its atom. Let light fall upon an electron, and let the vibration periods of the light and of the electron be the same; the electron would be excited by resonance and would absorb energy. The amount of energy absorbed might be sufficient for the electron to be shot out; in that case the energy absorbed would be equal to the energy of falling-in, and there would again be a quantum relation. But supposing the energy be insufficient for expelling the electron; there would only be conversion of light into energy of the same period, a transference leading to a scattering of light, without transformation of energy from one form into another; the quantum relation would again hold, however.

Whatever view we accepted as to the excitation of luminosity we should want the ejection of an electron, and the work required to eject the electron from the atom was therefore a fundamental quantity in the whole theory. We could not hope to excite luminosity unless we had enough energy to expel the electron. We should therefore expect to observe a sharp demarcation between the luminous state and the non-luminous state in cases where we were able to adjust the energy, and that was a well-known experimental phenomenon. In his demonstration, Sir Joseph used a vacuum bulb consisting of a tube widening out into a bulb, at the end of which was the anode; the kathode was a tungsten filament, joined to a special heating circuit and surrounded by a cylindrical sheath of copper, the kathode proper, which also shut off the glow of the filament—a bulb of the kind used as valves for radiotelegraphy. At first there was only a faint general luminosity. As the resistance in the filament circuit was cut out, the emission of electrons from the hot tungsten increased, and suddenly a bluish glow became visible in the space between the two electrodes; the appearance of the glow marked the moment when the stream of electrons carried sufficient energy to knock out the electrons from the gas atoms. The exact measurement of that energy, Sir Joseph continued, then was a matter of great theoretical importance which had attracted a great deal of attention of late, and Sir Joseph wished to refer to the interpretation of the results obtained. It was usually assumed that the energy to be given to the electron should be equivalent to the work done when the electron moved from one place to another. That was not necessarily so, however. If we wanted to move a load up an incline, say from A to B, it all depended whether the road A B were straight or not. If straight, then the work was merely that corresponding to lifting the load through the level difference between B and A. If, however, the road to B led *via* a hill C, we should have to do more work, though we could get back part of the energy afterwards when the load was sliding down hill on the path C B; to reobtain energy we had first to give it in any case, however. In such a case the electron would come out with a high velocity, and there was considerable evidence that, in certain instances, the electron was expelled with a definite velocity. The electron did not merely trickle out of the atom, but shot out with energy of a finite amount. A solid bombarded by kathode rays gave out rays of its own, secondary rays. The speed of the secondary electrons did not depend upon the speed of the primary ejecting electrons; we might increase the speed of the primary electrons considerably without altering the speed of the secondary electrons. That secondary speed seemed to be characteristic of the material, though it did not vary much from one substance to another. But Sir Joseph's point was this: when we measured the energy required to ionise a substance, *i.e.*, to drive out the electrons, we ought to be sure that we did not do more than drive them out. We ought to make sure that we did not first mount the hill C on our way to B, and thus cause the electron to be ejected with a finite velocity. That point might be at the root of the difficulty which some experimenters had experienced in calculating the energy involved. One of the most reliable methods of conducting these measurements made use of the radiotelegraphic valves above mentioned. When the current, passing through gases, was plotted as ordinate against the electromotive force as abscissa with the aid of these valves and other appliances, the current curve first rose steadily up to a certain potential and then continued to rise at a more rapid rate. That sudden increase in the current could be accounted for if, at that particular stage, another electron were knocked out of the gas so that an artificial increase of electrons was produced, so to say. The different methods yielded different results, and those obtained with the aid of the valves seemed to be the most consistent. A great deal of work had lately been done with valves for military and commercial purposes. When the energy required to ionise a gas had been deduced from such experiments, helium had been found to be the most difficult gas to ionise, requiring 20·1 volts. Mercury could be ionised by 10 volts, even by 5 volts, according to some experimenters. Nitrogen, strangely enough, had given the high value of 17 volts, higher than hydrogen, in some valves. In some valves an abnormal potential had been observed which did not correspond to that for any known gas. The valves in question had been made with a kind of tungsten which was not satisfactory. When a good tungsten was substituted, the peculiarity was no longer observed, and it had so far been impossible to trace the cause of the anomaly.

NOTES.

Ferro-Concrete Ships and the Classification Societies.

A report was presented in October last to the Committee of the Italian Naval Register, by their chief engineer, Ing. Domenico Barricelli, on the subject of ferro-concrete ships. In the course of this report, Mr. Barricelli gave a brief history of the construction of ferro-concrete ships in various countries and traced their development in the war period. He also referred to the papers on ferro-concrete ship construction read before the Institution of Naval Architects and other British associations, and dwelt at length upon the difficulties which faced classification societies in the inspection of ferro-concrete craft during construction. Inspection of a steel ship could easily be carried out at any moment during the progress of construction, with the result that the builders were able to presume that their work when completed was perfectly successful; such, however, was not the case in regard to ferro-concrete ships. The real efficiency of the means adopted for the union together of the various parts forming the reinforcement, and of the adherence of the latter to the material in which it was embedded could only be ascertained by means of experiments. Such experiments, which obviously were not necessary in the matter of a steel ship, could not be dispensed with in the case of a ferro-concrete one. According to Mr. Barricelli, the drawbacks under this head were greater in the case of the monolithic system, which now appeared to be the prevailing system, than in a system in which construction was carried out by sections or elements, since in the latter system a selection and a survey could be made of each element separately, tests rendering it possible to ascertain the quality of the material and its resistance to a specified stress before building up in the ship. He called particular attention to a system of concrete ship construction by such separate elements in use in Great Britain (Ritchie system); in this, the elements comprised floor plates and shell, side frames and shell, and deck beams, pre-cast in moulds, the various elements being of moderately large size, easily handled and easily subjected to tests after an adequate period of maturing. It was clear that this system, when experience had demonstrated its applicability to ships of large dimensions, was likely to simplify in a large measure the task of classification surveyors. At all events, whether the ferro-concrete ship were monolithic or built up of separate elements, owing to the very nature of the construction, however accurate may have been the design of the structure, and however scrupulously may the actual work have been carried out, it did not seem possible, so far, and without a definitive trial in actual service conditions at sea, to ascribe to the finished ship of ferro-concrete a degree of confidence equal to that which was justified in a ship built of steel.

Kathode Deposits of Nickel.

The opinion is sometimes expressed that electrolytic baths should give the same metallic deposits, independent of the compound decomposed, as long as the same metallic ions are liberated. But the

formation of kathode deposits is essentially a crystallisation process which, apart from impurities, depends upon the presence of crystal germs and the electrolytic conditions of current density, concentration, &c. Some metals, nickel in particular, show the peculiarity that they can hardly be deposited in layers more than a small fraction of a millimetre in thickness; as soon as that thickness is exceeded, the metal begins to split and peel off the kathode which bends inwards on the surface on which the deposit is being formed; the other surface of the kathode is, as a rule, varnished in order to limit the deposition of the metal to the one surface. Studying this peculiarity of the kathodic nickel deposition, V. Kohlschütter and E. Vuilleumier (*Zeitschrift für Elektrochemie*, October 1, 1918, pages 900 to 921) attached pointers to their kathodes, platinum foils of sufficient stiffness, in order to watch their bending. The attachment of the pointer did not prove an easy matter; finally a tape of platinum was coiled up to a small cone; the upper end of the tape was soldered to the lower edge of the kathode, and a glass pointer inserted into the cone. The upper edge of the kathode was clamped between jaws; any bending of the kathode would thus be about a horizontal axis and either inward or outward, the lower edge approaching the anode or receding from it. It was observed, with the aid of this "contractometer," that the bending started almost at once with the commencement of the deposition. It was an inward bending, indicating a contraction of the nickel deposit; it increased with the concentration of the bath and current density, and was strongly influenced by the addition of impurities, by temperature, and by other factors. When the bath evolved hydrogen, the contraction-time curves were regular; sometimes contraction set in again after periods of delay. A great many curves were obtained under widely-differing conditions. When the kathode was turned into the anode, so as to redissolve the nickel already deposited, the bending went back; when a bent kathode was charged with hydrogen, it straightened out again. When the circuit was then broken, and the hydrogen set free, the kathode rapidly returned to its contracted shape. The following explanation is suggested. The first film of nickel produced is of a highly-disperse form, the hydrogen also settling on the kathode constituting the dispersion medium. The metal then begins to sinter and to crystallise; this contraction stresses the kathode and causes the bending. When the conditions of the electrolysis favoured the formation of a fine grainy deposit or the immediate deposition of crystals, there was little or no contraction. Two phenomena have hence to be distinguished: the formation of a disperse film, and the contraction and crystallisation of this film, the case being analogous to that of kathode volatilisation of metals in various gases (hydrogen, nitrogen, argon, &c.) which Kohlschütter studied some years ago. The exceedingly thin films then obtained also coagulated, contracted and crystallised while changing their electric resistance.

Turbulence and the Inflammation of Explosive Gas Mixtures.

The influence of turbulence on the explosibility of gas mixtures and on the working of gas engines was, though not overlooked, not sufficiently heeded until recent years. Experimenting on behalf of the British Association Committee on Gaseous Explosions (Dundee, 1912), Dr. Dugald Clerk observed that the rate of explosion rise increased with the number of rotations and decreased when the turbulence was damped down. An engine working normally with ignition at the end of the first compression stroke attained maximum gas pressure in 0·037 second; when ignition was effected at the end of the third compression stroke, i.e., after turbulence had subsided, maximum pressure was not attained in less than 0·092 second. Agitating the gas-mixture contained in a closed cylinder by means of a fan, the late Professor Bertram Hopkinson found that with the fan at rest and at 2,000 r.p.m. or 4,500 r.p.m., maximum pressure was reached in 0·13 second, 0·03 second, and 0·02 second. That these figures must not in general be interpreted as signifying that increased turbulence would always increase the explosibility is shown by the recent experiments of Dr. R. Vernon Wheeler and Mr. M. J. Burgess (Journal of the Chemical Society, Transactions, January, 1919, pages 81 to 94). Dr. Wheeler tried mixtures of ethane and air which have a lower inflammability limit of 3·1 per cent.; in quiet mixtures containing less ethane than that, down to 2·9 per cent., the flame travels a little way and then goes out. But a mixture of 3·2 per cent. would not ignite in a cylindrical vessel when a fan was revolving in it at 100 r.p.s.; at 40 revolutions, ignition took place and a pressure of 4·5 atmospheres was developed; with the fan at rest, the explosion pressure rose to 3·4 atmospheres. In the 3·1 per cent. mixture ignition only took place at the fourth discharge spark when the fan was making 40 r.p.s.; with 20 revolutions, ignition ensued at once. The 3 per cent mixture could not be ignited at 100 r.p.s., but easily at 20 r.p.s. These mixtures were barely inflammable, and the point seems to be that in mixtures of low inflammability the igniting flame may be extinguished by strong turbulence before it has time to spread. Yet the 2·95 per cent mixture gave a higher maximum pressure with the fan at 20 r.p.s., than it should have given normally, so that in that case the flame seemed to have travelled further than it would have in the quiet mixture. From further experiments conducted with mixtures of ethane or of methane and air in a spherical vessel of 4 litres capacity, in the lower gland of which a fan was mounted, it would appear that the effect of turbulence is purely mechanical. In a quiet mixture the flame is propagated mainly by conduction of heat from a burning layer of the mixture to an unburnt layer; in the turbulent mixture the flame is forcibly dragged in the wake of the rapid current induced by the fan, and was, in some instances, carried round the vessel several times in a spiral whirl. In weak mixtures of the paraffins and air there is a considerable time-lag, that is, the flame has to travel an appreciable time and space before any pressure rise is indicated, because the temperature of the source of heat lies but little above the ignition temperature of the mixture. In stronger mixtures the combustion becomes distinctly more rapid with greater turbulence, and when the pressure maximum is plotted as ordinate against the time interval reckoned from the moment of ignition, the curves become more steep with increased turbulence, whilst the maximum pressure attained is hardly affected by the turbulence.

Federation of British Industries and South America.—Mr. W. S. Barclay, of the Federation of British Industries, has recently sailed for South America, to act as a Special Commissioner to conduct back to England the Brazilian delegates who have been appointed by the Brazilian Government to undertake a tour to this country as the guests of the federation. Mr. Barclay was attached to the recent Mission to Brazil under Sir Maurice Bunsen, and has therefore had exceptional opportunities of appreciating the problems of Anglo-Brazilian trade. At the end of the present tour of the Brazilian delegates the federation intends to send a permanent Commissioner to Brazil as part of its Overseas Commissioner Service. The federation, last autumn, entertained a number of Greek delegates. The federation intends to continue this policy of bringing delegates from abroad to this country and thus fostering, in every way, friendly relations between British manufacturers and potential customers from all over the world.

A New Source of Turpentine Oil and Rosin.—Turpentine oil and rosin are already being produced on a commercial scale in India by the distillation of pine rosin. A new source of supply, which, though comparatively small, may be valuable, especially for Indian use, has now been found in Indian frankincense or olibanum. This material is obtained by the natives by making incisions in the stems of *Boswellia serrata*, a tree widely distributed throughout the dry zone forests of Central India. The resinous substance which exudes from the cuts contains a kind of turpentine, a rosin and a gum. Investigations of the methods of separating these constituents in a marketable form, as to their commercial uses and value, and on the methods of tapping the tree, have been conducted since 1912 by the forest authorities in India in co-operation with the Imperial Institute, and the results of these have been published recently in a paper by R. S. Pearson, forest economist, and Puran Singh, chemical adviser at the Forest Research Institute, Dehra Dun. The general conclusion reached, based on the results of numerous trials carried out in India and in this country by the Imperial Institute, is that the turpentine oil is equal to good quality American turpentine oil, and that it could be used in place of the latter in the manufacture of paints and varnishes.

STATE REGULATION OF THE GERMAN COAL INDUSTRY.

The Bill for the State regulation of the German coal industry only contains the outlines of the new scheme, the details being left to the German Government to decide. In order to bring about a definite settlement of the question the Government is to enlist the services of a council of experts, comprising 45 members. Of this number 15 will be nominated by the employers, 15 by the consumers, and the remaining 15 by the Government. Of the latter number, three are to be selected from the coal trade, two are to be technical experts, one is to represent commercial interests, six more are to be selected from consumers of coal, and one each from coal-mining experts, coal scientists and transport. This council is regarded as a kind of Parliament of the interested parties, but whether it is to act simply as a kind of advisory body, or whether it will be able to make actual decisions, is not clear. It is not likely to be maintained as a permanent institution, and is probably only intended to assist in the framing of regulations, which will be drawn up by the Government and the council jointly. The council will, however, have power to revise, or even to repeal, the law later on, if this should be found expedient. The report of the Nationalisation Commission, which has paid special attention to the coalmining industry, will also have to be considered.

The Bill refers to coal, lignite, briquettes and coke, and, according to its provisions, the German State will undertake the industrial and general organisation of the industry through a State Coal Council. The Government will form the colliery owners of the different districts into various groups, which will, again, form a general union. The regulation of production, consumption and sale rests with the unions under the control of the Government and the State Coal Council; the Government will itself regulate prices.

An important feature of the new arrangement is the regular adoption of what have hitherto been known as coercive, or compulsory, syndicates. In the German lignite industry combines have been formed, or prolonged, through indirect coercion, but they have had to submit to a certain measure of State control, especially in the matter of prices. The latest prolongation of the Rhenish-Westphalian Coal Syndicate and the Nieder Lausitz Briquette Syndicate was only brought about because the authorities threatened to form other coercive syndicates; a similar official threat has also played its part in the fixing of prices. The point of the new Regulation Bill, however, is that the so-called "fear syndicates" formed as a result of the official threats just referred to, are changed into actual compulsory syndicates, and that the system not only applies to certain coal-mining districts, but covers the whole of Germany. The different syndicates are thus formed into one large syndicate by the State of Germany, and not by the authorities of the different States. As a result all the mining rights of the legislature of the different States will now be transferred to the State of Germany. In this way the management of the coal industry, which has hitherto rested with the producers, will now pass to a public organisation—the State Coal Council. It does not appear, so far, how this latter council is to be formed, but it will probably be on similar lines to the provisional Coal Export Council explained above.

The intention of the Bill is doubtless to organise the production, handling and sale of fuel in the interests of all concerned, according to a uniform plan, instead of in the interests of the producers only. It is not now a question of the State taking over separate collieries, or even the coal syndicates, but whether this represents the final stage or only a step towards nationalisation of the coal-mining industry remains to be seen.

The Institution of Municipal and County Engineers.—The forty-sixth annual general meeting and conference of this Institution will be held in Birmingham on June 26, 27 and 28 next, when it is proposed to discuss subjects relating to Housing and Town Planning, Sewage Disposal, Road Construction, Public Works generally, and to visit various works and garden suburbs. Further information can be obtained from the Secretary, 92, Victoria-street, Westminster, S.W. 1.

Contracts.—Amongst the recent orders secured by the English Electric Company, Limited, is one from the Nottingham Corporation for a turbo-alternator set of 3,000 kw. output, together with surface condensing plant and cooling tower; the contract also includes the supply of rotary converters and an equipment of Ferguson superheaters to existing Lancashire boilers, in order to secure economies in steam consumption with the new turbine. This plant will be installed in the two Nottingham power stations together with interconnecting E.H.T. switchgear and transformers.

INDUSTRIAL NOTES.

Speaking at a plenary session of the Peace Conference held in Paris on the 11th inst., dealing with the International Labour Charter, and under the presidency of M. Clémenceau, Mr. Barnes said that Labour had issued together with their report two separate drafts, one being the text of a scheme of international organisation, the other a collection of nine resolutions for insertion in the Peace Treaty or for issue therewith.

They had, Mr. Barnes further stated, provided for conferences of States, employers and workers to be held in the light of day, to be representative of all concerned, and to be armed with the fullest possible information. The business of the organisation which they proposed to establish would be to collect and distribute information, to stimulate healthy public opinion and to let light into dark places wherever such might be found to exist. The fundamental and effective idea of the organisation was the creation and mobilisation of humane public opinion.

Regarding the provisions of the document, Mr. Barnes added that, in the first place, its boundaries were made to coincide with those of the League of Nations. There were two reasons for this: First, because the League of Nations was invested with duties of a positive character and associated with the everyday work of the world and, secondly, because it brought all the sections forming the League into world co-operation for industrial improvement and thereby conveyed to Labour the impression that labour improvement was regarded seriously by the Peace Conference as a matter of world importance.

Secondly, it provided for an annual conference to be held, unless otherwise provided, at the seat of the League of Nations, the conference to consist of four members from each State, two being representatives of the State and one each of workmen and employers respectively. Each delegate would be allowed to vote separately.

In the third place, there would be a permanent office also situated at the capital of the League of Nations, whose business it would be to collect and distribute information, and which would be under the control of a governing body constituted in like manner to the conference itself, i.e., half of Government and half of non-Government elements.

After further explaining the charter and after a friendly discussion on various points in which delegates from various nations took part, Mr. Barnes moved:—

"That the Conference approves the draft convention creating a permanent organisation for the formation of the international regulation of labour conditions which has been submitted by the Labour Commission; instructs the secretariat to request the Governments concerned to nominate forthwith their representatives on the organising committee for the October conference, and authorises that committee to proceed at once with its work."

Sir Robert Borden, whilst offering his congratulations to the Labour Commission for its work, asked that the following amendment be added to Mr. Barnes' motion:—

"The Conference authorises the Labour Conference to make such amendments as may be necessary to have the Conference conform to the covenant of the League of Nations in the character of its membership and the method of its adherence."

Both the motion and the amendment were carried unanimously.

With further reference to our note on page 468 *ante*, we give below the results of the miners' ballot announced during last week end for and against accepting the Government settlement terms on the basis of Mr. Justice Sankey's report:—

	For.	Against.
Derbyshire	36,559	3,020
Durham County	95,648	6,825
Lanarkshire	32,138	5,766
Lancashire and Cheshire	56,154	12,090
Leicestershire	5,307	144
Midlothian and Haddingtonshire	7,011	1,637
North Staffordshire	18,744	641
Northumberland	30,489	2,855
Nottinghamshire	27,783	1,499
Stirlingshire	6,411	923
Wales, North	11,874	872
Wales, South	142,556	19,429
Total	470,674	55,701

The result of the ballot in Yorkshire was handed in at the meeting of the Council of the Yorkshire Miners' Association held at Barnsley last Saturday. The figures were not available for publication, but the majority in favour of accepting the terms is stated to be a large one.

Mr. Douglas Vickers, M.P. for the Hallam Division of Sheffield, addressed last Friday a meeting of the electors of the division, and in the course of his speech, dealing with the Ministry of Transport Bill, he stated that it contained a great deal of good, though perhaps it came as a shock to those who believed in private ownership rather than in State ownership. He was a railway director, and therefore to a certain extent he had the interests of shareholders at heart. He did not think, however, that in this case the interests of shareholders and the interests of the country were at all incompatible. He thought, in fact, that they were quite one, and, although he did not like the idea of Government ownership, he had come to the conclusion that it was right that railways should be nationalised. In the first place, increased wages had led to such a very large amount of expenditure, that something had to be done to make the railways pay. It would never again be possible to carry on the railways on the old competitive system, with its duplicated services, cheap trains, and luxurious travel. One thing alone had to be looked to in the future—the necessities for transport in the country. Nationalisation would make a good many other things possible and probable, including the provision of transport facilities for certain parts of the country which were neglected now under the conditions of private ownership. That was another reason why he would support the Bill.

Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, are converting their large projectile works at Scotswood, Newcastle, into locomotive works; they expect to have these works fully equipped afresh at an early date, for a production of from 300 to 400 heavy locomotives per annum, besides narrow-gauge and shunting locomotives. They anticipate commencing deliveries by next autumn. Their Elswick gun and gun-mounting shops are to deal in future with the building of marine engines of all types and boilers. Their Elswick steel foundry and their extensive drop-stamping plant are to be considerably enlarged. They contemplate also putting down a new iron foundry. Their shipyard is to undertake on a large scale the construction of all classes of merchant ships. The firm will also extend their construction of hydraulic cranes and dock gates, and will undertake contracts for bridge-building, structural work and other kinds of civil engineering enterprises.

Their Openshaw steel and machine-tool works are also being largely extended.

We read in *The Iron Age*, New York, that in order to provide positions for returning soldiers and sailors, the Sharon Steel Hoop Company, Sharon, Pa., has inaugurated an 8-hour day in the open-hearth department, instead of 10 hours. Other departments also will cut down the number of hours. It is probable that other steel plants in the Shenango Valley will introduce the 8-hour day schedule.

The extension of the 8-hour day at the Steelton, Pa., plant of the Bethlehem Steel Company is contemplated. The matter is, however, being left to a vote of the employees of the shops and mills, and votes recorded thus far are in favour of the basic 8-hour day. The adoption of the 8-hour schedule is designed, according to officials of the company, to give work to a greater number of men throughout the plant, during the unsettled period in the steel business.

The basic 8-hour day became effective in the plant of the Middletown Car Company, Middletown, Pa., producers of steel cars, on March 14. Three 8-hour turns will go into operation largely, in place of the two 10-hour and 11-hour turns. The plan is designed to aid in affording employment to returning soldiers.

THE MANUFACTURE OF PAPER YARNS AND FABRICS.

The manufacture of yarns and fabrics from paper has made remarkable progress in Germany during the war, owing, of course, to the shortage of jute, flax and cotton, resulting from the Allied blockade measures. Commencing with the production of coarser yarns suitable for making sacks, sandbags, twine, &c., the process of manufactures has been improved so that fine yarns, from which underlinen, bed sheets, upholstery materials, and many other fabrics of a similar nature, are now being made from paper.

The question of the success or failure of paper fabrics depends not so much upon the production of the yarns, as on the treatment of the paper necessary to improve its wearing properties, and to render it proof against the effects of moisture. Untreated paper is a weak, unstable material, and merely to twist a strip of it into a round thread will not add greatly to its capacity to resist wear or moisture. Hence the necessity for impregnating the yarn, without which the paper would dissolve into pulp if allowed to remain wet for any length of time. The problem thus seems to be one for the industrial chemist rather than for the spinner or manufacturer, and to what extent it has been solved may be judged from the fact that a paper under-garment of German manufacture felt quite soft, and appeared to be as good as new after having been washed sixteen times. The Germans, however, guard their trade secrets with the greatest possible care, and neutral agents who have endeavoured to acquire information as to the process of manufacture of such goods, have met with little or no success.

The so-called "spinning" of paper yarns presents no very great difficulties, and although special machines are made for the purpose, ordinary cotton-spinning machinery, modified for the purpose, is largely employed. Actually the process consists of twisting a narrow, flat strip of paper into a round thread, and roving frames are generally employed for the coarser "counts," and ring spinning frames for the finer ones. Machinery normally used for making fish-net yarns can, with very little alteration, be used for twisting paper. For all machines the principal alteration required is to the creel, which must be made to hold the paper strips rolled up into the form of discs; the twist gearing must also be altered to give the right amount of twist. In using ring frames, however, the question of the shape and weight of the traveller is a source of trouble.

The whole process of spinning is, briefly, as follows: Rolls of paper received from the paper mills are cut into narrow strips ranging from 2mm. to 8 mm. in width, according to the "counts" required, the lightest paper and the narrowest strips, of course, producing the finest counts. All yarns, it may be mentioned, are calculated on the metric system, 1,000 metres of 100 grammes weight being No. 1. The cutting machines are arranged so that the width of strip produced can be easily altered, and they are made to take rolls up to 80 cm. wide. After passing the cutting knives, the strips of paper run over a damping device, but do not come into direct contact with the water, and are then rolled up into discs about 30 cm. in diameter. These discs are then taken to the spinning frames, in which the paper strips are twisted into a round thread as previously stated. It may be noted that, owing to the necessity for the paper to be in a sufficiently damp condition for spinning, the strips must be cut at the spinning works, and not at the paper mills. The winding of paper yarns on cheeses, bobbins, &c., presents no great difficulties, but at all stages of the work the right quantity of moisture is essential for the production of a satisfactory thread.

Sweden, we understand, is now preparing to manufacture paper goods, and, having regard to that country's supplies of raw material in the form of pure cellulose paper, she should be in a particularly good position to take up the industry. Swedish manufacturers have obtained some small amount of information from Germany, and they are now carrying out the necessary alterations to a number of cotton-spinning machines, while awaiting the delivery of cutting machines ordered from Germany. One Swedish firm is endeavouring to manufacture both cutting and spinning machines similar to those used in Germany, but has not yet been able to design a satisfactory substitute for the damping device, which is a German patent. The cutting knives are also a difficulty, since those on the German machines are hollow ground, and Swedish firms are, apparently, unable to do the necessary hollow grinding. Thus in Sweden, but little progress has, as yet, been made with the industry, though several of the largest cotton-spinning firms are prepared to take up the manufacture of the coarser yarns for sacking, twine, canvas, and similar goods.

In Denmark practically nothing has yet been done, the position being that, while weaving firms are keenly interested in paper goods, the cotton spinners refuse to take the matter up for financial reasons, being doubtful whether paper yarns and materials will be able to hold their own in the textile market under normal conditions. Probably the position is somewhat similar in this country, but one firm here, viz., the Textilite Engineering Company, Limited, of 36 and 37, Queen Street, London, E.C. 4, is now making yarn and twine of various sizes, as well as sacks and bags, stair coverings, wall coverings, webbings, and other goods of paper, by means of machinery made in this country under patents owned by the firm. Samples of their products on view at the British Scientific Products Exhibition, attracted considerable attention and appeared to be well suited to the purposes for which they were intended. So far as we are aware no washing fabrics of paper were exhibited, there apparently being no demand for such materials in this country, even under war conditions, and the demand is not likely to develop in normal times when ample supplies of cotton, flax and other textile materials will be available.

Royal Institution.—The following are the lecture arrangements at the Royal Institution, after Easter: Professor Arthur Keith, four lectures on British Ethnology—The People of Wales and Ireland. Professor W. H. Bragg, two lectures on Listening under Water. Dr. H. S. Hele-Shaw, two lectures on Clutches. Professor Frederick Keeble, two lectures on Intensive Cultivation. Sir Valentine Chirol, two lectures on The Balkans. Professor H. S. Foxwell, two lectures on Chapters in the Psychology of Industry—(1) Fourier and Other Pioneers in the Movement for the Humanising of Industry; (2) Modern Industrial Organisation: Where it Fails to Observe the Humanities of Industry and the Results. Mr. J. Wells, two lectures—(1) Cæsar's Personal Character as Seen in his "Commentaries"; (2) Cæsar as a General. Mr. Julius M. Price, two lectures on The Italian Front. The Friday evening meetings, at 5.30 p.m., will commence on May 2, when Professor John W. Nicholson will deliver a discourse on Energy Distribution in Spectra. Succeeding discourses will be given by Sir George Macartney, Dr. S. F. Harmer, Sir Alexander C. Mackenzie, Sir John Rose Bradford, and Professor Sir Ernest Rutherford.

INVESTIGATIONS INTO THE CAUSES OF CORROSION OR EROSION OF PROPELLERS.*

By the Hon. Sir CHARLES A. PARSONS, K.C.B., F.R.S., Vice-President, and STANLEY S. COOK, Member.

THE corrosion or erosion of propellers has for many years engaged the attention of engineers and shipbuilders, and the capricious character of the action has rendered it difficult to assign an adequate and satisfactory cause to account for the observed results. At the suggestion of Professor H. C. H. Carpenter, a Sub-Committee of the Board of Invention and Research was formed in 1915 to investigate this subject. Those serving on this committee were Messrs. S. W. Barnaby, H. C. H. Carpenter, S. S. Cook, J. H. Gibson, Engineer Vice-Admiral Sir George Goodwin, and Sir Charles A. Parsons, with Engineer-Commanders Hawkes and S. R. Dight as secretaries.

The Admiralty supplied data in their possession on this subject, and information was also collected from other available sources; the investigations occupied about eighteen months.

The possible causes of corrosion or erosion considered may be stated under five headings:—

1. The nature of the surface of the metal and the state of the initial stress on this surface.
2. Stresses in the blades under working conditions.
3. Impingement of water at high velocity on the surface of the blades.
4. Cavitation.
5. Water hammer produced by the closing up of vortex cavities.

Each of these possible causes in turn was made the subject of investigation, and the following is a general account of the results:—

1. *Nature of the Surface of the Metal and State of Initial Stress in the Surface.*—The machining of propeller faces was reported to check erosion of the propeller blades to some extent, but examination of the material of a propeller blade before and after machining, carried out by Professor Carpenter, showed no difference in the metal except for a thin film of scale, &c., on the surface, about $\frac{1}{1000}$th in. in thickness. Nevertheless, there are advantages in removing this scale before the propeller is put into use.

Large propeller blades which, of course, cool slowly, evidently anneal well while cooling in the mould. This has two beneficial results: (1) Casting stresses are removed from the metal; (2) inhomogeneities present in the metal as cast are obliterated.

One firm had made a practice of hammering or planishing the driving faces of blades after machining, with a view to closing up minute openings that might lead to sub-surface cavities, but the advantages, if any, are open to question. On the other hand, the locally-stressed metal surface is possibly more liable to corrosion.

A comprehensive examination was made by Professor Carpenter of one of the eroded blades of a fast cruiser. A photograph of the eroded portion of this blade is shown in Fig. 1, above, and in Fig. 2, above, an etched cross-section of the blade traversing the main eroded area. Professor Carpenter's report to the committee is given in full in Appendix I. This examination failed to show any connection between the structure of the metal and the distribution of the erosion.

2. *Stresses in the Blades under Working Conditions.*—The committee initiated special experiments to determine the action of sea water on manganese-bronze under stress. These experiments were carried out by Professor Carpenter at the Imperial College of Science and Technology.

For studying the stress below the elastic limit, two machined strips of the metal, 1½ in. thick, which were perfectly flat in the unstrained condition, were strained by clamping the ends firmly together, while at the middle they were held apart by a ½-in. rod of the same metal. The arrangement is shown in Fig. 6, page 516, and a diagram of stresses is given in Fig. 7, page 516, from which it will be seen that the stress over the sides marked "B" varies from a maximum tensile stress of 40,000 lb. at the centre to a similar compressive stress at the ends, while at one point there is no stress at all. The assemblage was suspended in a glass tank by glass rods and was immersed to about the middle line "A A" in sea-water. The whole of the metal in this apparatus consisted of manganese-bronze of the same composition, so that all disturbing effects which might be caused by electrolytic action between different metals were eliminated. The sea-water used was obtained from the Channel off Dover. The concentration of the water was kept constant and the charge in the tank was renewed every week. This experiment, made both with cast manganese-bronze and with rolled manganese-bronze, did not show in either case that a steady stress throughout the range given above caused any acceleration in the rate of corrosion of the metal in sea-water.

For stresses beyond the elastic limit the test plates were removed from the apparatus and cleaned, bent into a horse-shoe form as shown in Fig. 8, page 516, by steady squeezing in a vice, and the ends clamped in position by a steel nut and bolt insulated from the metal. They were then half-immersed in sea-water, the entire gripping arrangement and the ends of the strip, for a distance of 1½ in., being covered with paraffin which protected them from contact with the sea-water. The sea-water was changed from time to time, and the experiment continued for one month. It was found that no action took place in either test, even at the position where the tensile stress would be a maximum; in other words, that steady stress well above the elastic limit, applied both in tension and compression, does not appear to cause any acceleration of the rate of corrosion in sea-water.

For alternating stresses, the test-piece consisted of a strip of metal 3 in. wide, 10 in. long, and ¼ in. thick. This test-piece was placed endwise in a tank of the same metal, one end being fixed to a stationary clamp attached to one end of the tank, the other receiving an oscillatory motion from a moving arm passing through the sides of the tank. This apparatus is illustrated in Fig. 9, page 516. The water-level in the tank was so adjusted

FIG. 1. GENERAL VIEW OF BLADE SHOWING CORROSION AREAS.

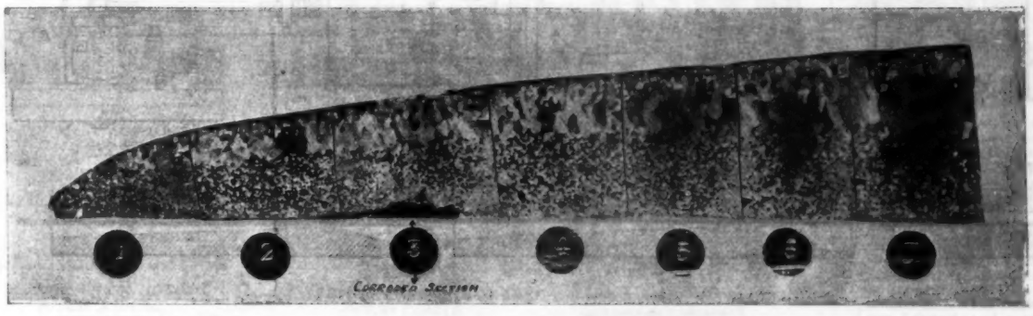
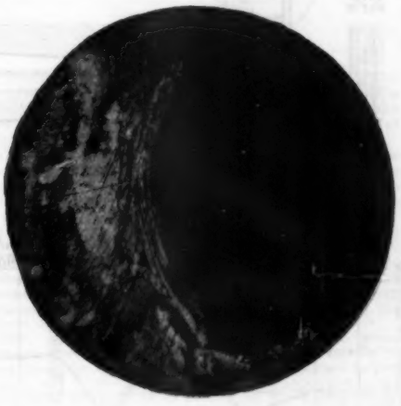


FIG. 2. CROSS-SECTION OF BLADE (ETCHED). SCALE, HALF FULL SIZE.

SECTION 4.

FIG. 3. TYPICAL STRUCTURE OF THE INTERIOR. × 50.



SECTION 3.

FIG. 4. CORRODED EDGE OF PROPELLER BLADE. × 50.

SECTION 1.

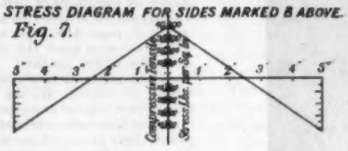
FIG. 5. SHOWING ABSENCE OF CORES. × 50.

* Paper read before the Institution of Naval Architects, April 10, 1919.

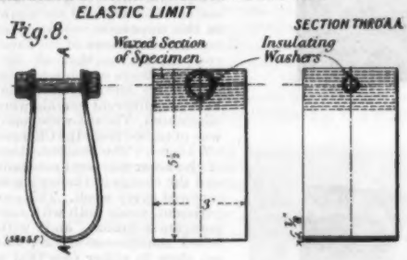
that only half the test-piece was immersed, thus allowing any acceleration of the corrosion at the surface of the water to be readily observed. The speed of oscillation was kept at about 60 per minute and the total stroke 1⅛ in., this being found to be the largest stroke which

SECTIONAL VIEW OF TEST PLATES
Fig. 6.
3-⅞ Dia. Steel Bolts

EXPERIMENT ON THE ACTION OF SEAWATER UPON MANGANESE BRONZE UNDER STATIC STRESS
STRESS DIAGRAM FOR SIDES MARKED B ABOVE.
Fig. 7.



TEST PIECE FOR ACTION OF SEA-WATER ON MAGANESE BRONZE STRESSED ABOVE THE ELASTIC LIMIT
Fig. 8.



could be employed without fracture of the specimen after a few oscillations. In various tests carried out with this apparatus using specimens of both rolled manganese-bronze and cast manganese-bronze, and lasting over periods varying from 167 hours to 358 hours, one alloy commonly employed for propellers was found to be almost free from any corrosive action, whilst a second showed only a very slight increase in the rate of corrosion in consequence of the alternating stress, and quite insufficient to account for the condition of some of the propellers which were examined by the committee.

Experiments were also made at the Turbinia Works, Wallsend, which showed that the alloys commonly used for propellers when subjected to steady stress, varying from 13,500 lb. per square inch in tension to the same value in compression, showed no increase in corrosion due to stress when subjected, in addition, to the action of a diverging jet of sea-water, in the apparatus described below (the specimen being a rod placed centrally in the diverging passage, whilst the initial pressure of the jet was sufficient to cause cavitation).

These experiments therefore gave valuable negative results, since the frequently-observed bending of the tips of eroded blades had been thought to indicate that stress was an important factor. Calculations were made independently by Messrs. Barnaby, Gibson, and Cook, of the distribution of pressure and the working stresses on a propeller blade, with the conclusion that these stresses did not normally reach excessively high values. In the case, for instance, of the propellers of a fast cruiser, the maximum estimate of the stress was from 9,000 lb. to 10,000 lb. per square inch, and this only at the root of the blade and far removed from the place of corrosion. An estimate of the position of centre of pressure furnished by the National Physical Laboratory from their experimental data of aerofoils did not indicate that any high stresses were likely to arise through irregular distribution of the pressure.

3. *Impingement of Water at High Velocity on the Surface of the Blade.*—Several experiments were made with jets of water, of pressures up to 1,500 lb. per square inch, on plates of various brass alloys, including those used for propellers, with the water impinging both normally and obliquely. These produced merely an etching effect on the surface of the metal. It should be remarked, however, that the scale of these experiments was small.

4. *Cavitation.*—Numerous experiments were carried out at the Turbinia Works, Wallsend, with jets having diverging mouthpieces, supplied with sea-water under pressure by a centrifugal pump, and discharging into a tank at atmospheric pressure. The velocity of the water was more than sufficient to sustain a vacuum and rupture of the water at the throat, in virtue of the diffuser action of the diverging mouthpieces. Under these conditions cavitation took place.

Various jets were employed. The most convenient form for purposes of observation was one of rectangular section, with top and bottom walls formed of curved slabs, and sides of flat glass plates. Jets Nos. 1, 2, 3, 4, were of this form, and are shown in Fig. 10, on this page. Jet No. 5 was a glass jet of circular cross-section.

A rod of the material to be tested, after being highly polished, was placed along the axis of the jet and there exposed to the action of the cavitating stream. The diagrams show the jets with the rods in the positions in which they were tested.

The sea-water was obtained from the North Sea, 3 miles to 4½ miles E.N.E. of the mouth of the River Tyne, at flowing tide.

In a second series of these experiments, carried out with the object of verifying the preliminary conclusions and of testing the effects under these same conditions of the additional circumstances of (1) stress, (2) the injection of the gases oxygen and CO_2 into the stream, and (3) annealing, a larger nozzle was employed, Fig. 11, below, and a more powerful pump to give higher jet velocities. This nozzle was formed by two shaped slabs of brass fitted between parallel walls of glass. It was thus of rectangular cross-section, 1 in. square at the throat, increasing to 1 in. by 4½ in. at the discharge. The rods were either ½ in. diameter or ½ in. square. The speed of the water was in all cases in the neighbourhood of 90 ft. per second, and under this condition cavitation occurred at the throat and extended for 5 in. or more beyond it.

In all 24 different rods were submitted to this treatment. One of these was of brass, 1 of Monel metal, 2 of copper, 14 of rolled manganese-bronze, and 6 of cast-manganese-bronze (5 of these were made from strips cut from propeller blades, in one case from a blade whose working face was deeply eroded).

The general character of the action on these rods, as revealed by the microscope, may be described as an etching of the surface, varying in degree. In the case of the Monel metal and the brass rods this action was very

SECTION THRO' A.A. SECTION THRO' B.B.

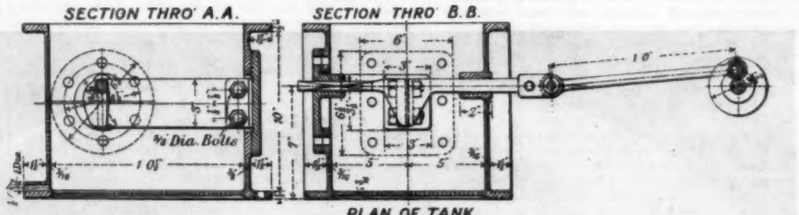


Fig. 9.
TANK & APPARATUS FOR TESTING CORROSIVE ACTION OF SEAWATER ON MANGANESE BRONZE UNDER ALTERNATING STRESS.

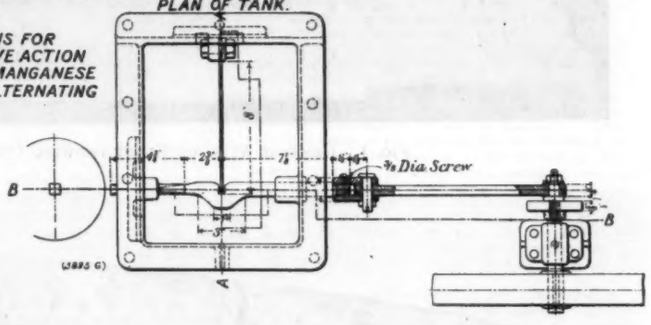


Fig. 10.

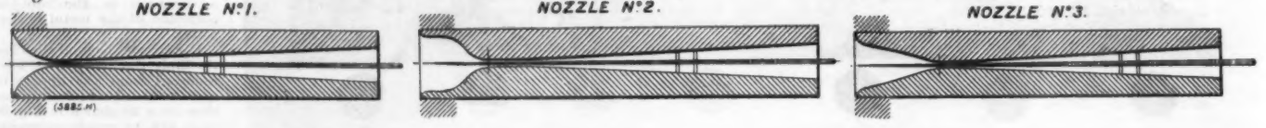


Fig. 11. RODS N°s 21, 22 & 23 IN NOZZLE N° 6.

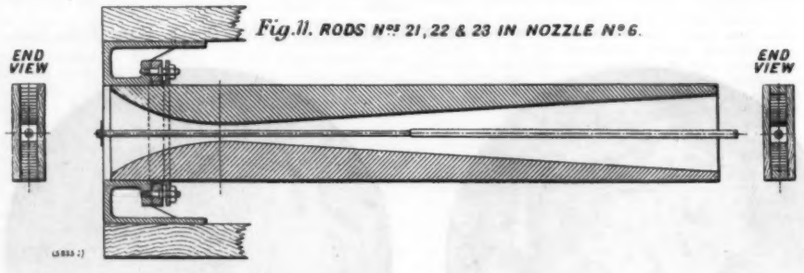
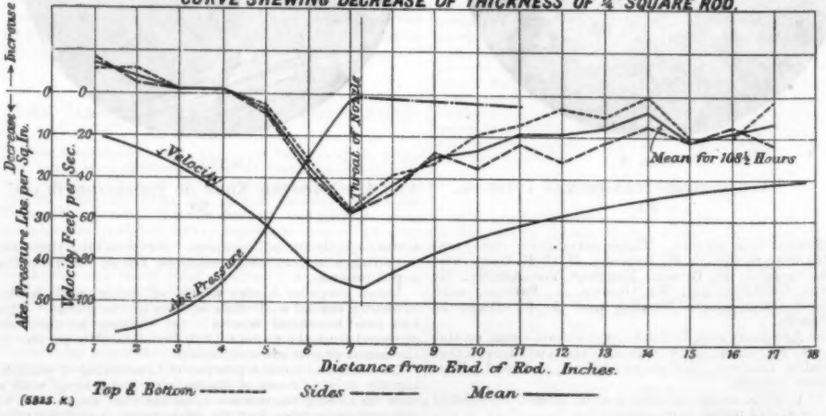


Fig. 12.
DIVERGING JET EXPERIMENT.
CURVE SHEWING DECREASE OF THICKNESS OF ¼" SQUARE ROD.


Decrease ← → Increase
Abs. Pressure Lbs per Sq. In.
Velocity Feet per Sec.
Velocity
Abs. Pressure
Throat of Nozzle
Mean for 108½ Hours
Distance from End of Rod. Inches.
Top & Bottom ——— Sides ——— Mean ———
(5885 K)

slight. In general, on the rods of manganese-bronze, there was incipient etching near the entry, increasing in depth towards the throat where the velocity was greatest. In some cases it continued deep to the end of the rods, and in other cases it gradually diminished from the throat onwards. In the incipient etching the chemical action by the salt water had just revealed the crystal structure. The rods were, to begin with, smoothly polished, so that the action was precisely similar to the etching of a specimen by acid for examination for microstructure. In the deeper etching, however, the material between the grains, and sometimes portions of the grains themselves, appeared to have been eroded away to a greater or less degree in different parts. Once the surface of the metal had been attacked the appearance remained the same, however deeply the etching penetrated, and the difference in degree was then only detected by measurement.

Fig. 12, page 516, shows curves of such measurements of the depth of the action, accompanied by curves of pressure and velocity. The general conclusion was that the degree of etching of these rods depended chiefly upon the duration of the experiment and the velocity of the water, and was not seriously influenced by liberation of gas, by stress, or by annealing; also that the effect observed did not exactly resemble either in character or in intensity the observed action on a propeller blade. Such action as was found appeared not to be attributable in any substantial degree to the cavitation, so that if, as was generally suspected, the erosion of propellers is associated with cavitation, some other and more intense form of cavitation must be sought which was not present to any great extent in these experiments.

5. *Water Hammer Produced by the Closing-Up of Vortex Cavities.*—Cases of rapid and deep erosion of propeller blades and the denting of the bosses, notably on the after propellers of the Cobra, in 1902, and on the after propellers of fast cruisers, as well as instances of undoubted deformation of metal by water hammer in water syrens, air pumps, and water pumps, led the committee to desire a theoretical and practical investigation as to the possible pressures that might be produced by the closing up of vortex cavities. The calculations which were made by Mr. S. S. Cook showed that very large pressures might be generated when vortex cavities are caused suddenly to collapse by the final concentration of the initial energy upon a small volume of the fluid. The calculations are given in full in the Appendix. The supposition is made that a certain portion of the fluid occupying, say, a sphere of a known radius, is suddenly annihilated, or what is the same thing, a rigid inner boundary to the fluid enclosing a vacuous space is suddenly removed, and the problem is to obtain the subsequent velocity with which the adjacent fluid flows into the cavity and the instantaneous pressure thus produced.

The calculations show that when a spherical vortex cavity in the sea closes upon a central nucleus of one-twentieth of the diameter of the original cavity, the instantaneous pressure or blow upon this nucleus may reach 68·2 tons per square inch, and if the diameter of the nucleus is one-hundredth of the diameter of the original cavity the pressure may reach 765 tons per square inch.

It also is shown that the pressure on impact is independent of the size of the cavities, and is only a function of the ratio of the initial to the final radii, so that very small cavities may cause erosion.*

A review of the instances of propeller erosion shows them not to be inconsistent with such a theory.

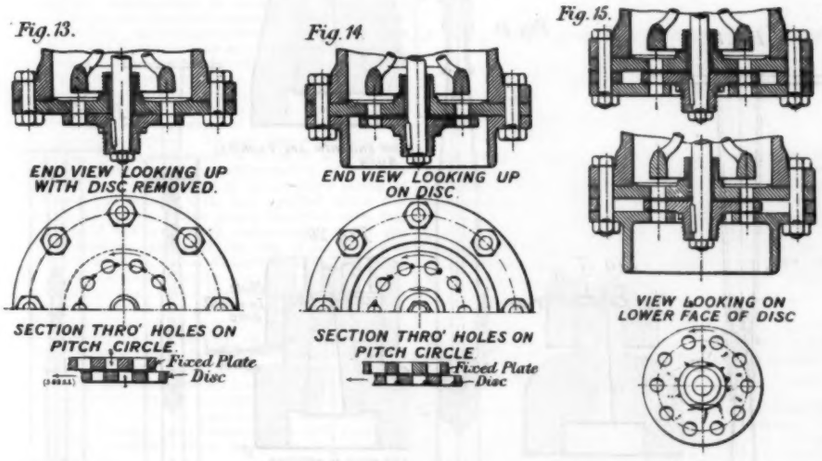
In the case of the erosion on the blades of the after propellers of the Cobra, there was also intense water hammer on the bosses, the bronze cover plates over the set bolts attaching the propellers to the shaft being driven in with such force as to take an impression of the numbers stamped on the bolt heads. More recently, similar action was observed on the after propellers of some fast cruisers, on those parts of the propeller blades which passed through the wake of the forward propellers. The forward propellers of one of these cruisers which showed no signs of erosion soon began to erode when transferred to the inner shafts, indicating that the erosion was due to the position of the propeller.

An exhaustive macroscopical and microscopical examination was made by Professor Carpenter of the blade of a cruiser's propeller which had been found to be eroded over nearly the entire surface, and which was excessively eroded in three well-defined areas. The effects of water hammer action were looked for, but very little evidence could be obtained owing to the similarity of structure of slightly-eroded metal, and that subjected to hammer blows. In two places, however, evidence of somewhat excessive deformation was found which may be attributed to this cause.

An analysis made of the surface layers of the eroded portions showed no difference in composition between them and the body of the underlying metal, and therefore gave no evidence of selective corrosion.

This theory of the action seemed also to be borne out by the variable positions of the patches of erosion, which were found on the blade tips, near the centre of surface, at the roots, or on the boss; but always in the same places on the blades of the same propeller. The blades in their rotation apparently cut the vortices from the forward propellers, or from the shaft struts, at the same place in turn, which would account for the similarity of pattern observed.

When propeller blades are found to be bent, the eating away of the surface is usually found on the side convex to the bend, and the bending might be accounted for by the water-hammer action stretching the surface on that side.



Erosion is also found where there is any inequality of the blade surface, *e.g.*, at the trailing edges of shackle holes through blades, and even centre punch marks show the same effect, appearing like little comets, of which the centre punch mark forms the head.

The time element in cases of propeller deterioration is of interest. In one case, at least, the propellers had to be renewed after a 3 hours' trial. Apparently the action, if it is going to occur, is most severe during the early life of the propeller and proceeds more slowly afterwards.

This might be accounted for by the erosion carrying the surface beyond the region of the nuclei of pressure (as in the siren experiment, described later).

Rapid erosion has occurred on the casings of air pumps of the drum or Root's blower type, on the delivery side, where the vacuous spaces would close up by the ingress of the sealing water.

Also, in a screw pump for circulating fresh water through a condenser, where cavitation was known to exist from the usual crackling or water-hammer noises, erosion was found all round the liner and opposite to the blade tips, where cavities caused by the blades would be closed up rapidly.

Also, in cases where the blades and hubs of propellers have been working in the wake of forward propellers, they have not only been rapidly eroded, but have in some cases shown the appearance of having been violently hammered, and near the tips the blades have been bodily bent.

To connect the ideal problem with the actual it remains to form a conception of the manner in which the cavities collapse in the actual case. It would seem that for our conclusions to apply, we must imagine a discontinuous action, that is, that the vacuous spaces are being continually formed and collapsed, rather than that they disperse along the surface as they move away from the place of their origin. And this may be the explanation of the capriciousness of the phenomenon. In a case, for instance, such as that of the Cobra's propellers, where there is reason to suppose that the after propeller blades cut across vacuous spirals trailing from the forward ones, we have here the very conditions for such a discontinuous action, and the pressure on the working faces of the after propeller blades would materially assist the collapse.

(1) *Water-Siren Experiments.*—Erosion was observed, very similar in character to that occurring with propeller blades, in some water-siren experiments by Mr. A. Q. Carnegie, of Messrs. C. A. Parsons and Co. The siren comprised a fixed disc, with 10 circular holes, perpendicular to its plane and regularly spaced on a circle of 2 in. diameter, followed by a moving disc independently driven and having a similar system of apertures. The space behind the fixed disc contained water under pressure, which discharged through the holes in this disc whenever the moving disc was in such a position as to allow of its escape. The latter disc revolving at a high speed, about 1,500 r.p.m., there resulted a rapid succession of interrupted jets. After short runs of a few minutes, the lower edges of the holes of the fixed disc were found badly eroded and laid over as by a mechanical process, Fig. 13, on this page. The following is the record for various metals used:—

—	Water Pressure.	Duration.	Erosion.
		mins.	
(1) Soft cast brass, Cu 85, Sn 6, Pb 4½, Zn 4½	70	10	Eroded too badly for use in siren.
(2) Rolled sheet brass, Cu 60, Zn 40	70	10	Slightly eroded.
(3) Manganese-bronze	70	10	More eroded than (2).
(4) Cast-iron ..	70	10	About the same as (2).
(5) Hardest air-blast cooled "Novo" steel (Hardness No., 650 Brinell)	70	10 70	Nil. Slight.

The erosion of cast-iron would indicate local pressures of about 50 ton per square inch, whilst to erode hard "Novo" steel the pressure must have been of the order of 150 tons per square inch.

Later, when using a short tubular mouthpiece extending to 1¼ in. below the fixed disc, Fig. 14, on this page, it was found that the erosive action was shifted from the lower face of the fixed disc to the lower face of the moving disc, the action being still of the same character, but more intense.

On extending the mouthpiece by the addition of an 18-in. copper tube, no erosive action was observed.

On reduction of the length of the mouthpiece to ¾ in., with a new disc of the same material, no erosion was obtained on either fixed or moving parts, except a slight pitting of the surface of the moving disc near the edges of the holes.

In a further experiment a second fixed disc with similar apertures was attached below the moving disc, the mouthpieces being in this case absent. No erosion was obtained on either the fixed or the moving discs.

On attaching the 1¼-in. mouthpiece below the second fixed disc, and shielding the moving disc by a tubular distance-piece between the fixed discs, the character of the erosion was again altered. There was no erosion in the neighbourhood of any of the siren holes, but a marked pitting in 10 small patches around the central boss of the moving disc (about midway between the siren holes), and severe erosion on the spanner flats of this boss, Fig. 15.

It is conceived that the action may be as follows:—

The momentum of each interrupted jet will momentarily cause a vacuous space to form behind it. There is an immediate inrush of water into this space from the side, and eventually back from the jet itself, as soon as the momentum of the latter has been destroyed. This return action by concentration finally produces very high velocities and pressures in a small volume of the fluid towards the interior of the cavity, giving rise, when the nucleus of pressure, or point at which collapse takes place, is located on the metal, to excessive water-hammering over a small area. The absence of erosion in certain cases as, for instance, with the 18-in. tubular mouthpiece, would be explained by a lowering of the collapsing position of the cavities and the final collapse occurring away from the surface of the metal.

The results obtained with the siren lent strong support to the view that propeller erosion is caused by a purely mechanical action.

(2) *Cone Experiments.*—To test the principle more directly a means was sought of producing such cavities under conditions involving spherical collapse. The following experiment was devised:—

A brass cone A, Fig. 16, page 518, was constructed, 18 in. long and 2½ in. internal diameter at the large end; at the small end it was reinforced as shown, and fitted with an end-piece B, the interior of which continued the cone and terminated with an internal diameter of 0·015 in. Ports D for the passage of water were provided in the side of the cone, near the mouth. This cone, placed under water in a tank, was allowed to fill with water, and then thrust quickly downwards, its mouth striking on to a rubber block at the bottom.

The sudden arrest of the cone by the rubber block gave a high rate of relative acceleration of its contents, producing momentarily a cavity at the apex, which, however, immediately closed again with a perceptible metallic hammering sound.

Efforts were next directed towards ascertaining the pressure reached at the apex. A cap of brass C, was attached as shown in Fig. 17, page 518, and thin plates of brass, of various gauges, inserted between the cap C and the end of the cone. Plates of ordinary commercial brass (about 60 per cent. copper, 40 per cent. zinc), up to 0·0035 in. thickness, were perforated in one blow. Thicker plates were severely dented. This would correspond to a pressure of at least 15 tons per square inch.

In experimenting with thin plates in this way it was

* Mr. Cook's calculations and conclusions were confirmed in a paper to the Royal Society by Lord Rayleigh (August, 1917).

found that after a few blows the effect was lost in consequence of the accumulation of a small quantity of air at the top of the cone. This difficulty was overcome by slightly slacking back the cap, which allowed this air to escape through the holes H. In one experiment with a moderately thick plate, about $\frac{1}{4}$ in., with the cap fitted so loosely as to allow the plate to move laterally, after 200 blows the plate was covered with small indentations, and its surface presented an appearance somewhat similar to that of a slightly eroded propeller blade.

To intensify the effect a modification of the apparatus was tried. The cone was lengthened by a cylindrical part to 4 ft., as shown in Fig. 18, below, and a lead weight fitted in the cylindrical mouth, suspended by a spring, and so placed as to uncover additional ports J during its descent. When this cone is thrust down to the bottom of the tank as before and arrested, either by a rubber block at the bottom, Fig. 21, or by a rope-sling round the handle, a loud metallic hammer is heard, especially noticeable in the case of arrest by the rope sling, since it is not then liable to confusion with any other noise.

The object of the lead weight was to increase the momentum of the contents of the tube. It is found, however, that a fairly loud report is obtained with this cone without the lead, though noticeably less than when the lead is in place.

With the lead plunger in position, a distinct click can be heard when the cone is merely dropped (about 8 in.) and arrested by the rope sling, but without the lead plunger no noise is obtained in this case.

With this larger brass cone, brass plates up to a thickness of 0·024 in. have been perforated. A plate of 0·03 in. thickness was severely bulged, but not punctured. The hole at the apex was about 0·02 in. diameter, having become slightly enlarged by the water hammer, so that the greatest thickness punctured was about 1·2 times the diameter of the hole. Allowing an ultimate shearing strength of 15 tons per square inch this would correspond to a pressure at the apex of at least 75 tons per square inch.

A striking demonstration of the cavitation is obtained by allowing some air to enter the cone (which is done by holding the cone for a short time with its apex above the water), and then striking it down at regular intervals until the air is got rid of. When this experiment is carried out with the cone arrested by means of a rope-sling there is practically no noise at arrest as long as air is present in the cone, and the return of the noise with the elimination of the air is most marked.

To facilitate examination, the cone was fitted with a separate brass end-piece, split longitudinally, as shown at F, in Fig. 19, on this page. The smallest diameter was 0·006 in. with a short parallel length for $\frac{1}{8}$ in. The inside of the cone was given a highly polished surface. After about 110 blows it was taken apart and examined. Severe erosion was found to have taken place at the end of the cone, and extending a short distance into the parallel portion. At the longitudinal joint the metal was severely crushed and a bulge produced at the upper end of the cone.

The solid cone end B, Fig. 17, used in the perforation experiments above referred to, was rebushed, with a hole tapering to 0·006 in., and a parallel of this diameter for $\frac{1}{16}$ in. An air-hardened disc of "Novo" steel (Brinell hardness number, 650), $\frac{1}{8}$ in. thick, and polished, was placed beneath the cap C, leaving sufficient freedom for air escape and movement, as above. On examination after 50 blows the steel showed no signs of erosion, but the cone end (of brass) was severely punished, the hole being considerably and irregularly enlarged, with radiating cracks.

A cone end-piece was next prepared of oil-hardened tungsten steel with a diameter at the smaller end of 0·015 in. Using with this a hard steel cap, a brass plate 0·03 in. thick was punctured at a single blow. A plate 0·035 in. thick was punctured in two blows. The puncture was nearly completed in a single blow, the metal being found, after the first blow, extruded for a distance almost equal to the thickness of the plate. The force required for direct shear of the periphery of the hole in a plate of this thickness would be $\frac{0{\cdot}035}{0{\cdot}015} \times 4 = 9.35$ times the shearing strength of the material, and taking the latter at 15 tons per square inch, the pressure must have been at least equal to, and probably greater than, 140 tons per square inch.

Attempt was made with this cone to obtain erosion of a hardened steel disc (also "Novo"). Forty blows, however, failed to produce any impression, but the steel cone piece itself was found to have fractured in an axial plane.

The steel cone end had been enveloped by an outer cone of brass G, Fig. 20, above, and since this was observed to have considerably enlarged during the experiments, it was replaced by one of unhardened "Novo" steel. A second solid cone end was prepared, and supported now by the steel outer cone G, gave practically the same results as previously obtained. A specimen of brass, 0·03 in. thick, was severely extruded by a single blow. A plate, 0·035 in., suffered considerable extrusion at a single blow, and was completely punctured with two blows.

These experiments have demonstrated the destructive power of collapsing water cavities.

Conclusions.—The conclusions arrived at are that the corrosion of propellers is very slight, but that erosion is serious and is caused by the hammer action of the water on the propeller blades, produced by cavities closing up on the surface of the blades.

This action may be caused either by cavitation of the propeller itself, occurring more generally when the propeller is in a varying wake, or by the cavities and vortices formed by the action of other propellers ahead of it, and the erosive action is generally aggravated upon a propeller which works in the wake of another.

The water-hammer action is also likely to be produced when violent and abrupt eddies are formed in the water by the form of stern frame, shaft bossing, or "A" brackets, or when the lines are very full and such as to cause an eddying wake.

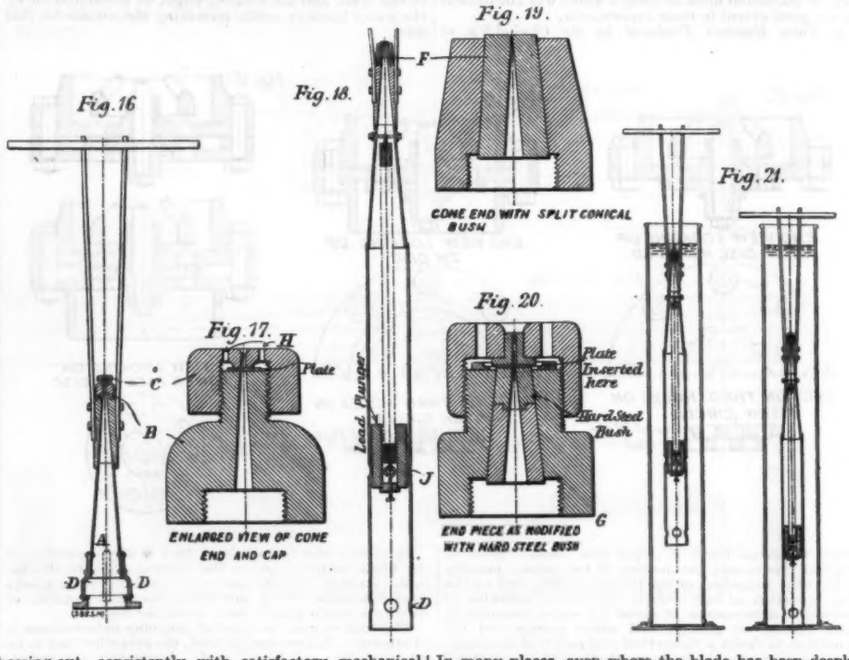
Cavitation will only produce erosion when accompanied by conditions which cause the cavities to collapse in such a way and in such a position that the energy of collapse is concentrated on a small portion of the propeller surface.

From the calculations (see Appendix II) it appears that the pressure of the water hammer is independent of the size of the cavity, depending only upon the ratio of its contraction, so that the cavities causing the erosion may be large or small. In the case of the propeller of a fast cruiser, inspected by the committee at the works of Messrs. Stone, some of the cavities which caused the erosion must have been large, as the dents observed in places were similar to those produced by using a round-nosed hammer. In the case of a certain single-screw ship of 11 knots speed, whose stern lines are full, the erosion of her propeller may have been caused by the cavities formed by the blades on their passage through the following wake, such cavities being carried with the blades and closed up suddenly when the blades entered those stream-lines of the vessel where the slip was normal (viz., about 11 per cent.).

In the case of twin-screw vessels, the propeller should be placed as far as possible from the after end of the bossing-out, consistently with satisfactory mechanical conditions of the support.

In the case of four-shaft vessels, the after propellers should, in addition, be placed as far as possible abaft the leading propellers, and as far as possible clear of the race of the leading propellers.

The form of the after edges of struts and bossings-out of very fast vessels should be designed and placed in reference to the stream-lines of the vessel with great care, so as to cause a minimum of turbulent wake.



APPENDIX I.

REPORT BY PROFESSOR H. C. H. CARPENTER ON THE "MACROSCOPICAL AND MICROSCOPICAL EXAMINATION OF SECTION OF A PROPELLER BLADE."

The blade, which measured about 4 ft. across at the widest part and 12·5 in. at the deepest part, was first cleaned with soap and hot water, and in this way a great deal of dirt was removed.

It was then photographed (Fig. 1, page 515) and afterwards carefully examined. It was found that some corrosion* had occurred over nearly all the surface of the blade, but that excessive corrosion was limited to three well-defined areas.

1. *The Edge Corrosion Band.*—A band on the extreme top edge of the blade commencing 10 in. from the left end of the blade and joining the main band approximately 16 in. from the opposite end of the blade.

2. *The Main Corrosion Band.*—Commencing 10 in. from the left side of the section and extending to within 6 in. of the opposite end.

3. *Twin Bands.*—Commencing 10 in. from the right end of the section and extending approximately 6 in.

1. *The Edge Corrosion Band.*—The corrosion extends to the extreme edge of the blade, its cross-section, 18 in. from the left end of the specimen, being approximately 1·25 in. It then decreases in cross-section until a few inches beyond the centre, when it again increases, eventually being absorbed in the main band 18 in. from the opposite end of the section.

2. *The Main Corrosion Band.*—This varies considerably in degree, but extends practically the entire length of the section, and is much deeper than the other bands. Its average width is approximately 3 in., but very marked corrosion has occurred on each side of this area. Towards the right end of the blade it spreads out, combining with the other corrosion areas. In this portion of the band the pitting is not deep. The maximum pitting is approximately 0·5 in. in depth, and was observed 18 in. from the left end of the section.

3. *Twin Bands.*—They have formed near the right end of the section, extend for approximately 6 in., and have a maximum width of 1·5 in. to 2 in.

General Corrosion.—This extends over the entire surface of the blade, with the exception of a small strip about 2 in. wide and 6 in. long, situated on the extreme right edge of the section, which appears quite unaltered and clearly shows the original scratches left by machining and filing.

The effects of water-hammer action were looked for, but very little evidence could be obtained, owing to the similarity of structure of slightly corroded metal and that subjected to hammering action. Over the larger portion of the section file marks can easily be observed. In many places, even where the blade has been deeply corroded, these marks are preserved owing to their having been more deeply eaten away than the surrounding metal. In other cases the file marks seem to have been obliterated in slightly corroded areas. Such areas were noticed 27 in. from the left of the specimen directly below the main band. The marks are also obliterated 29 in. from the end and 1 in. below the band, but can be clearly seen at this point 2 in. below the main band. This effect may be due to the mechanical wearing away of the metal caused by the rapid flow of water over the surface of the blade.

A complete cross-section of the blade was prepared for microscopic examination as follows: Over an area about 1 in. in width, on both sides of the blade, fusible metal was cast and allowed to freeze. A section of 0·5 in. wide was then cut, after which the fusible metal was melted off (in hot water). The section was then cut transversely into seven pieces (average width 1·7 in.). Round each of these was cast a layer of fusible metal. The sections were then filed, ground and polished for microscopic examination, after which the fusible metal was melted off. They were then etched. In this way a complete cross-section of the blade was obtained for microscopic tests with the original corroded profile absolutely intact and without any rounding of the metal at the edge, which would have made microscopic examination difficult. The seven pieces, mounted in a wooden frame, were photographed, and the result is shown in Fig. 2, page 515. The main corrosion band is contained in No. 3 section, from which it can be seen that the corroded area extends to a depth of about 0·5 in. It will be observed that the crystals, which are visible to the naked eye, are by no means of uniform size. Starting from the front of the blade they are comparatively small for a depth which varies from about 1·25 in. at the thickest end to 0·75 in. at the thin end. They are then abruptly succeeded by a zone of very coarse crystals which extend almost to the back of the blade, where a thin layer of small crystals occurs. This difference is no doubt partly due to, but is not entirely

*In the early investigations of the committee the word corrosion was used to describe the observed action on propeller blades, without prejudice to the question whether it was corrosion or erosion, that is to say, a chemical or a mechanical effect.

explained by, the fact that the blade after being cast cooled from the front side.

A typical structure of the interior of the blade, taken at a point which can be regarded as being outside the range of any water-hammer action, is shown in Fig. 3, page 515. Constitutionally the alloy is composed predominantly of a β constituent, but it contains a small amount of an α constituent as well. The latter appears a light gold colour in the specimen, but is seen in the photograph in the form of white spots and spikes dotted about irregularly. The β crystals vary considerably in colour—they may be golden, brown, blue, or purple. One of them, which has printed white, is seen in the centre of the photograph, Fig. 3, at a magnification of 50 diameters. Most of the β crystals are too large to be contained completely in the area shown. Of these two constituents it may be predicted that α will be the more easily deformed of the two. Accordingly a very careful microscopic examination of the front (corroded) edge of the blade was made with a view to seeing if any evidence existed of deformed α crystals. Only in two places was such evidence obtained.

1. Section 3 (which contains the main corrosion band) exhibited a small area extending about $\frac{1}{10}$ in. in which the α constituent very near the edge appears to have been flattened out into a strip. It is shown in photograph, Fig. 4, page 515, as a white curved strip near the bottom of a cavity created by corrosion, and it follows the curves of the cavity almost exactly.

2. Section 4 showed a similar structure in one place, but in this case the strip was much thinner and was situated at the very edge of the specimen.

Although evidence of the deformation of α was only obtained at these two places, it should be remarked that there appears to be no doubt about it, and that in each case the deformation is excessive. Tests were then made to see whether the α crystals deformed under mechanical strain. In the first place a machined section of the blade was hammered so as to produce a pattern similar to that on the corroded surface. Under this test the alloy deformed quite readily. A section was then cut at right angles to the direction of the strain and examined microscopically. In no place, however, was any evidence of the deformation of α noticeable. Severer stresses were then applied. In one case a specimen of the alloy was compressed under a stress of 25 tons per square inch. Here, again, no deformation of α could be detected. In another case a compressive stress of over 60 tons per square inch was applied when the specimen broke. It was then found that the alloy had taken the load without much deformation until the moment of fracture, and that the line of fracture was round the β crystals. No distortion of α could be found. All three tests, therefore, gave negative results, the reason being that under the conditions of the tests the alloy behaved as though it consisted only of the β constituent, of which it is very predominantly composed. The ductile α was held rigidly in the stiff β. These tests in my opinion throw light on the conclusions previously drawn with regard to the distortion of α at the surface of the blade under hammer action. They show that any considerable accumulation of deformed α at the surface is not to be expected on account of the small amount present, and, further, that such deformation must be confined to α which is not entirely surrounded by β.

NOTE BY PROFESSOR H. C. H. CARPENTER ON THE POSSIBLE INHOMOGENEITY OF PROPELLER BLADES AND THE QUESTION OF ITS EFFECT ON CORROSION.

The microscopical examination of the above propeller blade has thrown important light on a question raised by me at a previous meeting of the Propeller Sub-Committee. In considering possible means of preventing, or at any rate diminishing, corrosion, I suggested that the material of the blade may be inhomogeneous owing to the fact that the composition of the solid which first separates from the melt on freezing is not the same as that of the liquid depositing it; that layers of different composition may persist because the time of cooling is insufficient to enable them to be eliminated by diffusion; and that these layers may possess different solution pressures in sea-water, and hence aid in setting up selective corrosion or pitting. The microscopic evidence of such inhomogeneity is to be found in the appearance of cores in the crystals composing the alloy. Nowhere on the complete section examined (Nos. 1 to 7 inclusive) was any evidence of this nature visible. Even at the extreme tip of the blade where cooling is most rapid, and where, if anywhere, this phenomenon might be expected to be found, no trace of cores could be found. At all places the structure appeared to be that of a homogeneous alloy (Fig. 5, page 515).

I am therefore of opinion that, so far as large propeller blades of the same metal as the one examined are concerned, the rate of cooling is slow enough to produce an alloy of practically uniform composition, and that no special heat treatment is required. The question of some such treatment might, however, arise if cores were found in small, and therefore more rapidly cooled, propeller blades.

I wish to acknowledge the valuable co-operation of Mr. L. Taverner, A.R.S.M., in the foregoing experiments.

APPENDIX II.

MATHEMATICAL INVESTIGATION OF THE COLLAPSE OF WATER CAVITIES, BY MR. S. S. COOK, MEMBER.

In this investigation it is supposed that a certain portion of the fluid occupying, say, a sphere of known radius, is suddenly annihilated, or what is the same thing, a rigid inner boundary to the fluid enclosing a vacuous space is suddenly removed, and the problem is to obtain the subsequent velocity with which the adjacent fluid flows into the cavity and the instantaneous pressure thus produced.

The case of a cavity in a linear tube is capable, as will be seen, of a simple treatment. In the more general case, however, of an open fluid, it is necessary in order to ascertain the velocity at any stage of the collapse to suppose that the motion is that of an incompressible fluid. During the first part of the finite motion which preceded collapse, this assumption is justifiable for a liquid like water, the compressibility of which is about 1 in 20,000 per atmosphere of pressure.

One cannot, however, pursue the incompressible motion to the very end of the process. The estimate of the pressures generated by the arrest at the end of the motion must take cognizance of the elasticity of the water. It can be seen that the final velocity will be somewhat diminished by the compression of the water in the vicinity of the bounding surface, and the pressure generated consequently reduced. On the other hand, the decrease in the elasticity of the water for very high pressures is a factor tending to increase the resulting pressure.

From the calculations it will be noted that the pressure on impact is independent of the size of the cavities, and is a function of the ratio of the initial to the final radii only, so that very small cavities may cause erosion.

Linear Case.—The problem of finding the initial motion of a column of water in a uniform tube originally under pressure and then suddenly released at one end of the column, is analogous to that of a cut string, treated in Besant's "Dynamics of a Particle," chapter xiii, paragraph 237, edition 1893.

By equating the potential energy of a thin layer at the freed surface before release to the kinetic energy after release, we find at once the initial value of the velocity of the surface, thus:

$$\frac{1}{2}\frac{P^2}{\beta} = \rho\frac{V^2}{2g},$$

β being the compressibility modulus, and V therefore

$$= P\sqrt{\frac{g}{\beta\rho}} = c\frac{P}{\beta} = \frac{Pg}{c\rho},$$

where c = velocity of sound $= \sqrt{\frac{\beta g}{\rho}}$,
ρ = density.

As the disturbance travels back along the tube (with the velocity of sound c) the passage of the wave front releases the liquid from a state of rest at pressure P to a state of motion without pressure and with velocity V. The value of V can be confirmed from considerations of momentum. Thus, the increase of momentum of the moving part in time dt is the added momentum of the portion released in this time by the advance of the wave front $= \rho c\,dt \times V$. Equating this to the impulse $P\,dt$ we have as before $V = \frac{Pg}{c\rho}$.

If the tube is of finite length l, with an open end projecting into a reservoir of the fluid at the original pressure, the wave front of the disturbance caused by release will arrive at the open end in time $\frac{l}{c}$ and be immediately followed by a wave of compression travelling inward. The same considerations as before will show that at the new wave front the inward velocity is being increased by the same amount V. On the arrival of the wave at the free or released end of the column, the wave of compression is immediately followed by a return wave of expansion again accompanied by an increase of the inward velocity of the column of amount V. In this way the velocity of the column as a whole is gradually built up by each succeeding wave until it reaches the velocity due to the pressure head in the reservoir, which occurs after the freed surface has travelled a distance equal to rather more than $1\frac{1}{2}$ times the original length of the column.

If, now, when moving with this maximum velocity the column is arrested by a fixed barrier, or by a similar column moving from the opposite direction, the instantaneous pressure can be calculated by the same method as already employed for calculating the initial velocity of release. We have thus, with $V_n = \sqrt{2g\frac{P}{\rho}}$,

$$P_n = V_n\sqrt{\frac{\beta\rho}{g}} = \sqrt{2P\beta}.$$

If P = 2 atmospheres, β = 20,000 atmospheres, we thus obtain as a maximum limit to the instantaneous pressure:

$$P_n = \sqrt{80{,}000} = 283 \text{ atmospheres.}$$

Spherical Case.—In the more general case of an open fluid, it is necessary, in order to ascertain the velocity at any stage of the collapse, to suppose that the motion is that of an incompressible fluid. The general equations for a mass of incompressible fluid with spherical boundaries, and motion everywhere a function of radius and time only, are:

$$\frac{dp}{\rho\,dr} = \frac{du}{dt} + u\frac{du}{dr} \quad . \quad . \quad . \quad (1)$$

$$\text{and } u r^2 = f, \text{ a function of time only.} \quad (2)$$

In our problem, we suppose the fluid to extend to infinity, and to have a free surface at the surface of a sphere of radius R.

Equation (1) integrated gives:

$$\frac{p'-p}{\rho} = -\frac{1}{r}\frac{df}{dt} + \frac{1}{2}u^2 \quad . \quad . \quad (3)$$

where p' is the pressure at infinity.

At the free surface $p = 0$, and therefore:

$$\frac{df}{dt} = R\left(\frac{1}{2}u^2 - \frac{p'}{\rho}\right) \quad . \quad . \quad (4)$$

The acceleration at the free surface is:

$$\frac{Du}{Dt} = \frac{du}{dt} + u\frac{du}{dr}$$

$$= -\frac{1}{r^2}\frac{df}{dt} - \frac{2u^2}{r} \text{ by (2)}$$

$$= \frac{-1}{R}\left(\frac{3}{2}u^2 + \frac{p'}{\rho}\right) \text{by (4)} \quad (5)$$

and therefore, since u at the free surface $= \frac{dR}{dt}$, we have the following differential equation to express the position of the free surface at any time:

$$R\frac{d^2R}{dt^2} + \frac{3}{2}\left(\frac{dR}{dt}\right)^2 + \frac{p'}{\rho} = 0 \quad . \quad (6)$$

for the first integral of which we have:

$$\left(\frac{dR}{dt}\right)^2 = \frac{2}{3}\frac{p'}{\rho}\cdot\frac{R_0^3 - R^3}{R^3} \quad . \quad . \quad (7)$$

If we suppose the free surface to strike a sphere of radius R, the pressure instantaneously generated by impact is that obtained by equating the potential energy of the surface layer after impact to its velocity energy before impact, viz.:

$$\frac{P^2}{2\beta} = \frac{1}{2}\rho\left(\frac{dR}{dt}\right)^2$$

$$= \frac{p'}{3}\cdot\frac{R_0^3 - R^3}{R^3}$$

$$\text{or } P = \sqrt{\frac{2}{3}p'\beta}\,\frac{R_0^3 - R^3}{R^3}$$

where β = the compressibility modulus, expressed in the same units as P and p'.

The following are the values of P for various values of R/R_0, with $p' = 1$ atmosphere, and $\beta = 20{,}000$ atmospheres:—

R/R_0.	P (Tons per Sq. In.).
1·0	0·0
0·5	2·02
0·2	8·5
0·1	24·2
0·05	68·2
0·01	765·0

It would appear that the instantaneous pressure in an actual case depends upon the original size of the cavity in relation to the coarseness of the structure of the material on which it collapses. One may take, for example, the case where a hemispherical cavity collapses on to a plane metal surface coinciding with its diametral plane.

The assumption of incompressibility implies propagation of the disturbance into the exterior fluid at an infinite speed, and in consequence the instantaneous establishment of a pressure gradient from the freed surface outward. In the actual case the wave front of the disturbance will travel outwards at the velocity of sound, and if p be the pressure and u the velocity immediately behind the wave front, we have, as the front of the disturbance crosses a spherical layer of radius r:

$$\text{Potential energy released} = \frac{p'^2 - p^2}{2\beta} r^2 c\,dt$$

$$\text{velocity energy created} = \frac{1}{2}\rho u^2 r^2 c\,dt$$

$$\text{and work done on adjacent fluid} = -p u r^2 dt$$

$$\text{therefore } p'^2 - p^2 = c^2\rho^2 u^2 - 2p u c\rho$$

$$\text{or } u = -\frac{p'-p}{c\rho}$$

agreeing with the value of the velocity given by the theory of sound for small motions.

Thus the velocity at the free surface immediately after release has the small value $-\frac{p'}{\rho}$ outwards, or $\frac{p'}{c\rho}$ inwards, instead of zero as previously found on the assumption of incompressibility. The acceleration behind the wave front, in the initial motion, when this motion is small and the fluid incompressible, can be shown to be $-\frac{p}{\rho R_0}$ outwards, or $\frac{p'}{\rho R_0}$ inwards (in gravitational units $\frac{p'g}{\rho R_0}$), and this is the same value as already determined on the assumption of incompressibility.

The circumstances of the initial motion are therefore practically the same whether we assume the fluid compressible or incompressible, in spite of the fact that this motion is derived in the one case from the elasticity of the surrounding fluid, and in the other from small motion of the distant fluid. In the subsequent motion the compressibility of the water will not begin to affect the results until the pressures in the fluid immediately surrounding the cavity reach very high values.

THE WORK OF THE BRITISH MARINE ENGINEERING DESIGN AND CONSTRUCTION COMMITTEE.*

By A. E. SEATON, Member.

ALTHOUGH the conception of this Committee did not originate in this Institution of Naval Architects, its actual formation was so largely due to this Institution that I think it is appropriate that the latter should be the means of conveying to its members and the members

* Paper read before the Institution of Naval Architects, April 10, 1919.

of those other institutions constituting this Committee some account of the work it has accomplished and of the methods and means by which it has succeeded in drawing up and putting into workable form the proposed rules and recommendations relating to marine boiler construction which are now in their hands.

The ultimate aim with which it started, and perhaps the most pressing object the Committee then had in view, was the unification of all the rules which govern the design and construction of marine machinery, especially of those pertaining to boilers. I think that none of the members of the committee quite grasped at that time what that expression exactly meant, nor did they appreciate the task that had been undertaken. We do know now, however, and we believe we have arrived at the real solution by producing an entirely new set of provision instead of making from the old ones a sort of engineering mosaic by piecing fragments together and using as the cement extracts from the most recent products of science and practice.

In the process we have gained a knowledge of many things about which our ideas had previously been somewhat hazy. It has indeed been an educational course, and by following it and eliminating from our minds all prejudice and thus treating each case on its own merits, we have arrived at results which we believe will command the confidence of shipowners, their superintendent engineers, and of all those in charge of and in attendance on boilers, as well as of the men engaged in their design and manufacture; and further, it will ease the minds of all who are responsible for boilers both during the period of guarantee and afterwards.

For these reasons we hope that the new rules will be found equally acceptable by the Board of Trade as by the registration societies, and be used by them all as a means of ensuring the safety and efficiency of boilers designed and constructed for marine purposes, whether they be placed in the smallest of tramp steamers or in the bowels of some mighty Atlantic express liner. The committee do not desire by anything they have published to intrude into what may be called the domestic side of the registration societies or of the Board of Trade. They do, however, sincerely hope and would strongly urge that between them all there shall be only one code by which design and construction shall be governed, and they do not hesitate to express the opinion, with all due respect, that the proposals now put forward will permit of that consummation. Such has been the great desire throughout, and added to it there has always been, in coming to every decision, the proviso that safety came first and foremost while efficiency was maintained as far as possible.

The committee had to examine and consider four sets of rules which, more or less, had controlled both the design and construction of marine boilers. In some cases only one set was operative; in others there were two to be taken account of at the same time, whose forms were different, while their results were often practically the same. But sometimes they differed to such an extent as to be incompatible with one another. In every such case, however, two sets of calculations had to be made, and the materials for construction were subject to double inspection, if not with double tests, all of which involved waste of time, and an unnecessary expenditure of money.

The incidence of these rules varies so much both in quality and effect as to require a considerable amount of differentiation at the outset. A shipowner is free to select the registration society with which he shall class his ship, under whose inspection his ship shall be built, and in accordance with whose rules her machinery shall be designed and made. But if he wishes her when built to carry more than 12 passengers, he has no choice but, *nolens volens*, to go to the Board of Trade for a certificate stating that she is fit and safe for such a purpose. If the boilers have not been designed in accordance with the rules given for guidance to the Board of Trade surveyors, or if they have not been inspected by them during construction and the materials tested by them, these boilers are deemed to be not fit for the pressure which the registration society's survey has permitted. Now it seems to be an anomaly, if not something worse, that any Government authority should allow 12 passengers and the captain, officers and crew of a ship to go to sea with boilers which they consider unfit for 13 passengers. If these boilers are unfit for the one ship, surely they are unfit for another; and to suggest that boilers which have undergone the survey inspection, &c., of the officers of a responsible body such as Lloyd's Register are not safe and reliable for passengers seems hardly credible and certainly is not warranted.

But the committee had to face the above facts and to find justification for putting the rules of the registered societies on the same footing as those of the Board of Trade.

To begin with, however, they found that another important Government department, devoted to the consideration of all matters engineering matters, viz., the Admiralty, had some years ago practically employed the rules of Lloyd's Register in the design of cylindrical boilers of all sizes for use in His Majesty's service; and that whatever rules the Admiralty had used in recent years, the thickness of the shell plates of naval boilers was no more than those given by Lloyd's rules and very much less than those permitted by the Board of Trade. They found also that while the rules of the British Corporation and of the Bureau Veritas differed in form, the results obtained from them practically agreed with those of Lloyd's Register.

Now the registration societies are voluntarily constituted bodies, who are quite free to make and insist on compliance with the rules for the construction of boilers as for every other part of a ship that is to receive their *imprimatur* of classification, that is, to have a class assigned which is to owners, shippers and underwriters a sure indication and warrant of character. Their rules may be absolutely arbitrary if their committee so decide, but we know that they are not so; for these committees have voluntarily provided safeguards for the prevention of this possibility. Not only are these rules formulated by engineers of eminence who have had both scientific and practical training, and are under a full sense of responsibility for their actions, but they have had to pass the scrutiny and criticism, and have received the final approval of a committee of experts before being put into operation. They are also reviewed and subject to further criticism by these committees and, if thought necessary, amended and brought up to conform with modern requirements and to accord with the latest knowledge. The officers of these registries vie with one another in friendly competition in this direction; nor are their consultative committees backward when dealing with such matters.

With the Board of Trade things are somewhat different. To begin with, they have statutory authority to do certain things, but they have no competition or other active motive to spur them on, or even to make them keep abreast of the times. There is, therefore, always the temptation to "wait and see." No Board of Trade officer will gratuitously take risks which may bring censure on himself, while he may get no recognition, however successful his efforts may prove. His sole function is to certify that a boiler or some other part of a ship is safe according to rules given him for guidance. If he has any doubt, as the late Sir William Siemens once said to the members of this Institution, "the remedy to which the surveyor flew is an added quarter of an inch somewhere."

Notwithstanding all this, the committee felt that it required some temerity to turn down a Board of Trade rule, and to adopt one from the registration societies, seeing that the sole function of the Board of Trade was to ensure safety on a ship.

The members of the committee, however, took heart of grace when it was brought home to them that there were, after all, many thousands of boilers of all sizes designed and constructed in accordance with the rules of Lloyd's Register and other societies, which were still working at the assigned pressures without bursting and apparently without any serious trouble—not even mishaps—in all parts of the world and under very varying conditions. That such boilers are efficient in every sense of the word must be so, or surely owners would soon have complained, and their complaints would have been voiced by the Technical Committee in such a way as to be heard by the Chief Surveyor.

The committee also remembered that when the Board of Trade first issued instructions to their surveyors and formulated rules for the construction of boilers forty-six years ago, the material then used was iron only, and that was of varying and uncertain quality: none of it was ever subjected to tests either mechanical or chemical. It is true the internal parts of boilers were then generally made of best Yorkshire iron plates, but the shells which were subject to tensile stress and considerable strain could be made of anything which would bear dropping on to hard ground and be sheared and punched cold. The rivet holes were punched and "faired" by reamering so that the rivets might be put in place without too much force, and closed by hand hammering.

The number of plates in a boiler shell was then quite three times as many as is usual now, with three times the number of joints to make and keep tight; with very large boilers the difference was even greater still. Under these circumstances it was easy to understand that the so-called Factor of Safety should be high, so that nobody could complain at a factor of 5 even when the boiler was well made with what was then deemed good material.*

To-day we have a very different state of affairs. Now all material is produced under supervision; it is carefully tested and every care taken by both registration societies and Board of Trade surveyors that none but fit and proper material shall be used in boiler construction; and not only so, but there is insistence that it shall not be injured nor rendered less fit by any operation during construction. The holes are all drilled in place after the plates have been bent to shape. They are, therefore, perfectly fair with one another, and the spaces between them uniform; the rivets are also closed by hydraulic pressure, and with substantial heads and snaps formed on them so that the grip of the plates against sliding is now very positive and efficient, and is not affected by the heavy caulking which is now a thing of the past.

The boiler is no longer designed as to details and scantlings by the foreman boiler maker in his office, but by an expert and skilled draughtsman in accordance with definite rules. In fact, the marine boiler is now so designed and constructed as to be safer even without any hydraulic test than were the older boilers with one; and they really require such a test much less than do the engine cylinders and fittings through which the steam passes from them.

At the outset the committee had to consider the meaning and bearing of the expression "Factor of Safety," as the Board of Trade lay so much stress on it. It was examined and found to be really a figure of speech rather than any assurance for the safety of a boiler. It is, in fact, merely the ratio of the ultimate stress required to rupture the plates to that which they are subject to when the pressure in the boiler is that allowed on the safety valves by the Board of Trade rules. For a boiler 15 ft. in diameter and a working pressure of 200 lb. per square inch, the Factor of Safety by the 1918 Board of Trade rule was 4·5; by the British Corporation it is 4·01; by the Admiralty it is 3·3; by Lloyd's rule it is 3·96. For thicker plates, as with larger boilers and higher pressure, Lloyd's factor becomes less, so that for a boiler 17 ft. diameter and 200 lb. working pressure it is 3·87. That is to say, a boiler made under Lloyd's rule for 200 lb. pressure would pass for 194 lb. by a rule which had 4 as a Factor of Safety. In other words, the difference allowed is 3 per cent., or putting it another way, 6 lb. of the margin of 200 lb. which it is supposed to have before permanent deformation could take place is used up. With the old Board of Trade factor of 4·5 the working pressure was only 173 lb.

It was concluded that such a boiler as would be passed by Lloyd's could not be destroyed by the rupturing of the shell, seeing that Mr. Traill had failed to burst the shells of the old iron boilers with which he made experiments years ago. Further, there was no manner of doubt that such shells would be quite safe against any pressure that might by chance, in a natural way, accumulate in them. With a Factor of Safety below 4, however it was considered to be unwise to put a hydraulic pressure on boilers, whereby that factor became less than 2 at the test.

It was also concluded to be quite unnecessary now to test boilers by water to double the working pressure; in fact, there is the possibility that instead of such a proceeding being a source of safety, it will become a cause of damage to the structure, especially to the staunchness or tightness of the joints. The opinion has been expressed and strongly supported that the test pressure should no longer be any multiple of the working pressure, but rather that it should be an added excess such as is provided in the rules of the British Admiralty and many foreign authorities. The committee would have been content with 100 lb. margin over the working pressure as being sufficient for every purpose for which such a test is designed. They were willing, however, in deference to the view of the Board of Trade, to adopt for the present a rule which was still a multiple, but also had an added constant, viz.:—

"Hydraulic test pressure is to be 50 lb. in excess of one and a half times the working pressure for all new boilers, but is not to exceed one and a half times the working pressure for boilers which have been in use."

Consequently the following obtains for the hydraulic test of a boiler the working pressure of which is 200 lb. per square inch:—

If for the British Admiralty 290 lb., viz., W.P. with 90 lb. added.

If for the French authorities 285 lb., viz., W.P. with 85 lb. added.

If for the German authorities 275 lb., viz., W.P. with 75 lb. added.

If for the Italian authorities 271 lb., viz., W.P. with 71 lb. added.

If for the Board of Trade (Marine Department, 1918) 400 lb., viz., twice W.P.

If for the Board of Trade (Land) 300 lb., viz., $1{\cdot}5 \times$ W.P.

As recommended by the committee, 350 lb., viz., $(1{\cdot}5 \times \text{W.P.}) + 50$ lb.

That is, the margin in this case over working pressure will be 150 lb. by the rule proposed.

But even with this the Board of Trade are not content for they have established recently the minimum limit of 1·75 times the working pressure, so that for a boiler made for 240 lb., it must be tested to 420 lb. instead of 410 lb. by the rule; or against the 330 lb. which would satisfy the naval authorities, or to the 360 lb. with which another department of the Board of Trade is satisfied for locomotives, which not only draw trains in the open country, but stand in the midst of hundreds of passengers in stations.

The committee have had in mind, when dealing with shell plates, furnaces, stays, &c., that the load on them is always applied and removed in the gentlest way possible; that during those operations as well as while the load is carried, there is very little variation and, such as there is, made without shock. Under these circumstances such a material as steel may be trusted to sustain continuously for an indefinite period quite a high stress—such a stress indeed as might be dangerous to structures subject to serious changes in intensity of stress, and especially so if liable to shock in the process.

Such a stress may be quite a half that necessary to produce permanent set, and, therefore, more than a quarter that of the ultimate strength—that is, the so-called Factor of Safety may be less than 4.

Formerly marine boilers were liable to a considerable amount of corrosion; the deterioration due to this cause was the same whether the plates were $\frac{7}{8}$ in. or $1\frac{1}{4}$ in. in thickness. To provide for this Lloyd's Register rule contained an added quantity of $\frac{1}{8}$ in. or, as we call it now, $\frac{4}{32}$ in. The Board of Trade rule contained no such provision.

Moreover, the Board of Trade have no responsibility for the lifetime of a boiler, their certificate being for one year only. This certificate is renewable only on the annual examination of the boiler, whereas the registration societies have to consider a very long life for the boiler.

The amount of corrosion in marine boilers is now generally very slight, and with carefully kept ones it is negligible. The committee, however, decided to continue the provision for the possible contingency, and also by way of tolerance for blemishes and inequalities of thickness in the plates, but were satisfied that $\frac{2}{32}$ in. was sufficient. They also have carried out this method of tolerance and allowance for possible corrosion throughout the rules.

Table I gives the working pressures which would be allowed by the different authorities on some boiler shells made of plates whose ultimate tensile strength is 30 tons

* In the earliest rules the Factor of Safety was $5 + A + B + \ldots$ The reduction to 4·5 was made later.

TABLE I.—WORKING PRESSURES ALLOWED IN VARIOUS BOILERS BY THE RULES OF THE SEVERAL AUTHORITIES, WHEN MADE OF STEEL HAVING AN ULTIMATE TENSILE STRENGTH OF 30 TONS PER SQUARE INCH.

Internal Diameter. In.	Thickness of Shell Plates in 32nds. of an Inch. Strength of Joint, 84 per Cent.																													
	(i) 24 = 0·75 in.							(ii) 32 = 1 in.							(iii) 40 = 1·25 In.							(iv) 48 = 1·5 In.							(v) 56 = 1·75 In.			
	A.	B.T.	L.R.	B.C.	B.V.	F.S. 2·8	B.M.C.	A.	B.T.	L.R.	B.C.	B.V.	F.S. 2·8	B.M.C.	A.	B.T.	L.R.	B.C.	B.V.	F.S. 2·8	B.M.C.	A.	B.T.	L.R.	B.C.	B.V.	F.S. 2·8	B.M.C.	L.R.	B.C.	F.S. 2·8	B.M.C.
220	79	85	90	92	91	90	94	135	114	126	125	123	123	129	191	142	162	158	155	155	163	248	171	198	192	181	188	197	234	225	221	231
200	96	94	99	101	100	99	104	158	125	138	138	135	135	141	220	157	178	174	171	171	179	282	188	218	211	199	207	217	257	248	243	254
180	117	104	110	112	111	110	114	186	139	154	153	150	150	157	254	174	198	194	190	190	199	325	209	242	235	221	230	241	286	275	270	282
160	142	117	124	126	125	124	129	220	157	173	172	169	169	177	297	196	222	218	213	214	224	375	235	272	264	249	259	271	322	310	303	317
140	176	134	141	144	143	141	149	264	179	198	197	195	193	202	353	224	254	249	244	244	256	442	268	311	301	284	296	310				
120	220	157	165	168	167	165	173	323	209	251	229	226	225	236	426	261	296	291	284	285	299											
100	282	188	198	202	200	198	207	406	250	277	275	271	270	283																		

A by the British Admiralty Rule. B.T. by the Board of Trade Rule in 1918. L.R. by the Lloyd's Register Rule. B.C. by the British Corporation Rule. B.V. by the Bureau Veritas Rule. F.S. 2·8 by the Board of Trade Rule in 1919. B.M.C. by the Rule of the British Marine Engineering Design and Construction Committee.

and with longitudinal joints, the strength of which is equal to 84 per cent. of the solid plate.

The committee have, of course, recognised throughout that any rule which is to command respect must be made with due regard for the material to which it is to apply. They came to the conclusion that, in a general way, it was best to adopt the rules and tests of the British Engineering Standards Association, and to recommend for use in the manufacture of marine boilers the materials there specified. It is therefore specified that, in general, boiler shells and longitudinal stay bars shall be made of the standard 28/32 tons tensile steel; that flanged portions and those parts exposed to flame, also screwed stays and rivets, shall be of the standard 26/30 tons tensile. Steel manufacturers would then be able to keep stocks of ingots and billets, and even have some plates ready for conversion, and thereby reduce both the cost of production and time of delivery.

At the same time it should be observed that the committee make no attempt to dictate in such matters, for it is always open to any boiler maker to apply for and to get permission to use steel of even a higher tensile than 35 tons should he so desire; or he may use 26/30 tons steel for boiler shells if he prefers.

As regards furnaces, the committee's rules are modified from the existing ones in the direction of increasing rather than decreasing the thickness of the corrugated and ribbed variety, and of limiting the thickness of the plain sorts.

The rules for the staying and stiffening of flat surfaces have been modified chiefly with the view to rendering the rules more elastic, and thereby giving the designer greater freedom in the choice of scantling as well as in methods of design and construction.

The stresses permitted on stays have been increased somewhat, but those proposed are still very moderate, even after the stays are corroded to the full extent provided for in the rules.

With regard to the screwed stays there was some controversy. The number of threads, 9 per inch as recommended by the British Engineering Standards Association, was finally accepted as practically the best for all diameters; also that the number of threads, 6 for the larger stays, should be accepted as satisfactory. The material suitable for them was examined, and it was found both by the evidence of those who had had considerable experience with them, and that obtained from some experiments carried out at the desire of the committee, that wrought iron as made from the products of the puddling furnace withstand both corrosion and the stress coming on them when the boiler is at work better than those made from an ingot produced material, even when the chemical compositions are practically identical.

The length of the screwed stays in proportion to their diameter was thought to be an important factor in considering the durability of those connecting the combustion chambers to the boiler shell. It seemed that endurance depends very much on the angular displacement which occurs through the differences of temperature and expansion of the chamber plates and shell plates; also that the longer they were in proportion to the diameter the more elastic would be the structure, and, therefore, less tendency to strain particular members of it.

In the United States of America the naval authorities insist on having screwed stays made with axial holes as was at one time common in this country with locomotives and in the naval boilers of locomotives type, where they served the double purpose of providing means for expanding the stays tight in their holes and of showing by leakage of steam when the stays had become fractured. The committee recognised this latter advantage as one of value as a means for avoiding an enlarged field of fractures with calamitous results, but did not think it was a matter for compulsion in this country.

It was found that whereas all material used for screwed and other solid stays must be tested and proved fit for service, there was no such safeguard provided by any body for stay tubes. These are usually of iron in the Mercantile Marine, with no evidence or warranty as to its origin, strength or elasticity.

It was also noted that while the Board of Trade had a definite rule for fixing the thickness of the smoke tubes, there was no expressed criterion for the quality of their material. The committee had evidence which left no doubt that it was often very indifferent, and even sometimes so poor as to break away in the process of expansion in the tube holes when done by a roller expander.

After a friendly conference with the leading firms engaged in the manufacture of these tubes, the committee were able to draw up an acceptable specification for use whereby the quality and supply of these tubes will in the future be satisfactory without being any more costly than formerly.

Experience in the Mercantile Marine with smoke tubes made of steel does not appear to have been such as to encourage their further extended use. On the other hand, in the naval service, steel smoke tubes are in exclusive use and they have given every satisfaction.

The committee have come to the conclusion, however, that if such tubes are made of very mild steel with an ultimate tensile strength not exceeding 26 tons per square inch, neither the general corrosion nor the pittings will be any worse than that experienced with iron ones. Such tubes will be no more costly and probably be easier to obtain, due to the general and ready supply of basic steel suitable for the purpose, and therefore more easily obtainable than puddled iron products.

It was not, of course, really a function of this committee to standardise the details; they were, notwithstanding, of opinion that the time had come when something of the sort should be attempted whereby economy in manufacture could be effected without any sacrifice of efficiency. This committee have made some few reforms in a tentative way which will to a small extent pave the way for the work of the committee which has been recently appointed for this express purpose, so that it may continue the process to an extent deemed desirable for economic ends.

For the vertical type of boiler there appeared to be no very special or definite rules in existence. As these boilers have been and still are in very general use, especially those of the Cochrane type, both for auxiliary purposes in all classes of ships and for the main machinery in smaller vessels, the Committee decided that it ought to establish such rules as would ensure that these boilers shall be as safe when made in accordance with them as are the ordinary horizontal cylindrical boilers.

As the fittings and mountings of a boiler are beyond question required to be as carefully designed and manufactured as the boiler itself, the committee have devoted considerable time to the consideration of all that pertains to them. The use of steam at high pressure and consequent high temperature had years ago imposed on the makers of stop valves, safety valves, &c., the necessity for considerable improvements in design, and greater care in the selection of material for their construction as well as in the workmanship. To-day, with even higher pressures and with the steam superheated to 550 deg. F., and in some cases even higher, it is absolutely necessary to use only such material as can show a fairly good elongation with sufficient strength at those high temperatures. For the boxes cast steel, and even good cast iron, is quite trustworthy; but the ordinary bronze formerly used by engineers is not so. For at even comparatively low temperatures the copper tin bronzes lose much of their tenacity and more of such toughness as they possessed when at 100 deg. F.

It has been shown that by the addition of small quantities of lead to such bronzes, they can maintain good strength and toughness even up to 550 deg. F. There are also other bronzes which are strong and tough at 600 deg. F., and in some cases at even higher temperatures. For the valves and valve-seats of stop and safety valves, care should be taken to use only such bronzes as possess these properties.

Cast iron can now be easily supplied with a tenacity of 9 tons per square inch without trouble or extra cost; the Committee are, therefore, justified in demanding that mountings and fittings exposed to boiler pressure shall be made of such cast-iron. When the temperature exceeds 420 deg. F., it considered that steel should be used, as it retains a toughness at that and higher temperatures such as to command confidence, even more than the very high tensile cast-iron now obtainable. In fact the cast-iron now in use by engine builders is so much better than that employed when the Board of Trade rules were made, that there is good reason for a reconsideration, if not a complete removal, of many of the vetoes contained in the book of instructions, and likewise there is good reason for a reconsideration of the unqualified confidence reposed in brass as compared with cast-iron for many fittings.

Considering that to-day the use of natural draught—that is, the very moderate pressure produced by chimney exhaust—is becoming to a great extent limited, and that with forced draught now so common the rate of combustion due to it as well as to the quality of the fuel burnt, causes the product in the form of steam to vary very much; and, further, seeing that so many boilers now have no grates at all, the area of grate can no longer be taken as a reliable criterion for the size of all safety valves. The Committee have therefore decided to turn to the total heating surface as a surer and more certain basis for the purpose of deciding the size of safety valves, inasmuch as this is a fixed and unalterable quantity, easily ascertained, and has always been taken in specifications and contracts as the measure of the power or capacity of the boiler for steam production. Moreover, heating surface has been adopted long ago by the marine authorities in several foreign countries as well as by locomotive engineers and others in this country as the basis for such calculations.

It is quite true that the production of steam per square foot of surface may be increased very considerably by extreme forcing of the fires or by using fuel of very high calorific value; but in practice in a merchant ship the limit of production is not difficult to estimate, and by the Committee's rule the boilers will have valves sufficiently large to pass all the steam made under even extreme mercantile conditions. Moreover, they will be such as have been usually fitted to similar boilers having an equal amount of heating surface and subject to forced draught designed to accord with the Board of Trade rule. Moreover, the sizes as so prescribed are limiting minimum ones; it is therefore open to any one to fit larger valves if they are not deemed sufficient to pass the tests for accumulation. The committee were not concerned with extreme cases such as may occur with naval ships but must be extremely rare in the Mercantile Marine; its function was simply to find a rule for guidance when dealing with the boilers in everyday use, which would ensure that valves made in accordance with the rule would in practice pass as much steam as the boiler could produce.

Incidentally the committee were induced to question what was really meant by the title of "Safety Valve," and how it fulfilled and justified this title. In the very early days, with box boilers made of thin plates, untested materials, and by hand labour for a working pressure of 10 lb. or even 20 lb. per square inch, a very small amount of accumulated pressure would approach the danger-point; in fact 20 lb. beyond the load on the valve might have caused serious local damage to such a boiler, even if it did not effect structural damage and blow it up. To-day an additional 20 lb. would have no deleterious effect whatever. This, however, is the limit allowed by the Board of Trade rules for a boiler, the working pressure of which is 200 lb.

With modern boilers having such large margins of safety as they really possess, it seems very wasteful that the safety valves should be so large as to dissipate so much potential energy every time the normal demand on the boilers for steam is checked for the moment from such causes as arise out of the navigation or temporary derangement in the engine rooms. It is to avoid some of this waste that the committee propose that only one valve on each boiler shall be loaded near to the working pressure allowed, while the others shall have a higher load.

It was pointed out that while the size of the valves and passages leading to them should vary inversely as the pressure per square inch, this rule did not apply to the waste steam pipe, inasmuch as the pressure in it varied only slightly; and that whether the load on the valves is 60 lb. or 260 lb. for the same length of piping, the diameter should not be very different. It is true that with the higher pressure at the issue from the valves there will be a higher pressure at issue from the waste pipe, and, consequently, there might be a smaller pipe. But the committee came to the conclusion that as the difference was so small there should be one rule only which, while providing a somewhat large pipe for high pressure, was not too small for any low-pressure boilers. It was also thought there should be a limit to the load on any individual valve so as to keep the springs and gear generally within reasonable and workable sizes.

For the high pressures now obtaining, and likely soon to be higher, throughout the Mercantile Marine, ordinary stop-cocks are by no means satisfactory, inasmuch as, if they are packed tight enough to avoid leakage, the plugs are difficult to turn. Moreover, the shells are very liable to deform sufficiently under high pressure and high temperature to permit of considerable leakage. They do possess, however, certain good features which are absent from valves generally; attempts have been made with a fair amount of success to produce a valve which will answer every purpose that a cock serves. The necessity for a really good substitute for a cock is now recognised, and the com-

mittee expect that the demand will so stimulate invention as to produce a supply of even better valves than those which are acceptable now as answering their purpose.

Troubles with steam pipes still continue to be experienced, and the casualties in the machinery department of ships arise more often from damage to pipes than to either boilers or fittings and mounting. The committee decided, therefore, that it was a duty incumbent upon it to examine into the causes and to establish rules and other means whereby these troubles should be eliminated. It was clear to the members that however well the pipes were designed and made, and of whatever material they were constructed, there would be no real safety unless adequate and effective means were provided for anchoring the lines of piping so as to take the thrust due to pressure as well as to expansion when hot. It was also equally necessary that there should be provision for permitting longitudinal expansion without entailing an unnecessarily severe thrust either on the anchorage or on any of the parts to which the pipes are connected. Furthermore, as the line of piping is in a ship in motion and liable at times therefore to severe shocks, and always to a very considerable and violent amount of movement from the waves' action, it must be hung and supported, or in some good way secured to avoid straining at the joints at each end and at all intermediate parts. For such things no precise rules or formulæ can be made; nevertheless attention to these points is of paramount consideration, and especially in large ships and ships which are full of machinery.

Copper which had been so largely—almost exclusively—used in the past for every sort and size of pipe on account of its malleability and the ease with which it could be brazed and jointed to flanges is no longer a necessity. From its inherent softness it stretches on very little provocation, and is therefore quite unfit for general engineering purposes; it is also liable to serious deterioration by "gassing" when being brazed or exposed to heat for normalising or any other purpose. Moreover, in continuous service it acquires a crystalline state that renders such heat treatment to normalise it a necessity. Our predecessors were apparently in happy ignorance of these things, and they derived satisfaction from the careful way in which they planished all their important copper pipes, and thus hardened the substance and made its surface beautiful, and thereby raised the yield point very considerably.

After consultation with two or three eminent metallurgists and manufacturers of copper pipe, the committee decided to discourage the use of all brazed copper pipes; to encourage and even in certain cases to insist on the use of solid drawn ones, and to prohibit their use altogether with steam over 180 lb. pressure when the diameter exceeds 6 in.

The stress allowed by the Board of Trade rules for copper pipes is really much too high, unless there is alloyed with the copper, arsenic or some other equally beneficial element whereby the yield point is raised above 6,000 lb.

The committee now insist that only arsenious or other equally strong copper shall be used, and that tests must be made of it to ensure that coppersmiths and engineers shall have such material as to warrant the thicknesses given by the rules.

Iron and steel steam pipes have been in use for a considerable time, but the rule of the Board of Trade which was applied to determine the thickness of every sort and size of iron and steel pipe was based on the first trials with wrought-iron ones made by welding or riveting of plates made with untested material and by hand treatment in ordinary smiths' fires.

To-day solid drawn steel pipes can be obtained up to 24 in. diameter, and welded steel and iron ones of any size. But the Board of Trade have not in the past permitted steel pipes to be used when simply welded only; if a pipe is labelled "steel," it is required that a cover strap be fitted over the weld and riveted to the pipe. If there is no restriction as to the nature or quality of the steel, this is probably a wise precaution; but the same may be said with good reason of that which is labelled "iron," and which proved to be such.

The committee caused very searching inquiries to be made as to the welding properties of both iron and steel, and, further, they tried to discover what tests should be applied to either material to prove its capacity for reliable welding. The results were such as to convince them that iron and steel can be welded equally well if the proper kinds of metal are used. That if ingot iron or if very mild steel were used with clean fires or gas flames, and if the process of welding involving the working of the metal by hammering or rolling, the jointing could be depended on quite as surely as if the material were iron produced from a puddling furnace. It was decided therefore that, provided those conditions were observed and the materials had been proved as fit for the purpose, there was no need for any cover strap.

The stress permitted on solid drawn steel pipes by the Board of Trade had been only 3,000 lb. per square inch, the same as was allowed on welded iron or even on copper. Lloyd's and the British Corporation rules, however, had allowed 6,000 lb., and the British Admiralty 6,740 lb. The committee considered therefore that 6,000 lb. was reasonable and by no means too much; and although with this allowance the thickness of pipe prescribed may be too small in some cases to permit of screwing on the flanges, there is nothing to hinder any one from supplying them of greater thickness if that method of flange attachment is preferred.

There are, however, other methods of attaching flanges, and it is to be expected that invention, when stimulated, will produce still more, so that thinner pipes may be used in ships where weight of machinery must be kept down. For the smaller pipes, if need be, the makers could swell the ends as they do for stay tubes.

In conclusion, I would like to report that the attendance of your representatives, as also those of the other institutions and societies, has been throughout most satisfactory.

The members of the committee represent every branch of marine engineering as well as every district in the kingdom. They have all evinced the greatest interest in the proceedings; they have not only joined in discussions, but have frequently by correspondence with me been most helpful in elucidating problems which have arisen sometimes and caused a considerable perturbation before arriving at the solution. Some of our members have even carried out at considerable expense and personal sacrifice of time during the most trying period of the war some important experiments. They have come from far and near to take part in the work, and consequently no single important point has ever been discussed, and much less settled, without the presence of a considerable number of members.

The two members who were co-opted to advise the committee on questions of steel material, Messrs. R. J. Butler and Benjamin Talbot, have been very helpful, and Mr. Milton with his great knowledge of and experience with all the metals used by marine engineers has been a tower of strength to the committee, and especially so when copper and bronzes were considered.

I have been, and we all are, under great obligation to the manufacturers of plates, bars, tubes, both steel and copper, for the information and advice they have given so very ungrudgingly, when the demands on their time and attention must have been much greater than in pre-war days. To Sir Gerard Muntz, Mr. Tomlinson (of the Broughton Copper Company), Mr. Stewart (of Stewarts and Lloyds), Mr. Trevorrow (of the Chesterfield Tube Company) I am particularly obliged. From such scientific investigators and metallurgists as Sir Robert Hadfield, Professor Harbord, Professor Ripper, Mr. John Dewrance and others I have received most courteous treatment and very much useful information for which we are all grateful. Engineer Vice-Admiral Sir George Goodwin, K.C.B., has taken a lively interest in our proceedings and shown a willingness to help us with such advice as only an experienced naval officer can give.

To Mr. Tobey, of the United States Embassy, our thanks are also due, for he has taken an interest in the committee, and on more than one occasion obtained information from the United States of America regarding experience there. He has offered to obtain further information if we require it, and to help us in any other way.

The committee have desired on more than one occasion to have research and experiments made on a scale beyond the means at their disposal, especially was this necessary in order to determine certain questions which otherwise could only be matters of surmise or deduction.

It had been hoped that the Research Committee so long desired would have been formed before this and have rendered us the assistance we have often required. Apparently, like the Spanish fleet in the play, "It is not yet in sight" so far as we are concerned. A wealthy shipowner has recently given 20,000*l.* to build the vestibule of a cathedral. Can some other equally generous owner of ships make an equally large contribution for a vestibule to a temple of science and research whereby we may enter and undertake investigations which would more than repay him and any of his brother shipowners who may join him in such an enterprise?

The great regret we experience, however, is that our labours have not had that recognition and appreciation from the Board of Trade that have been accorded us by the three registration societies, as it is hoped that all will benefit equally by the work of the committee.

I have adverted to what I believe are the advantages of consultative and advisory committees in engineering matters. Our present rulers evidently are at one with me in my belief in the use of such committees, judging by those that have been appointed in connection with the administration of matters relating to the air, the sea, and the land.

Two former presidents of the Board of Trade have many years ago done that service for the Marine Department of the Board of Trade. Lord Bryce, so far back as 1895, suggested and approved the formation of a consultative committee to help that department's technical officers as effectively as had been done for those of Lloyd's Register. That committee was then formed, and this Institution has had four active representatives on it ever since. It has met regularly four times a year, and has done some most important work; it still continues to do so, but it has never yet been consulted by the Board of Trade or by its technical officers.

Our present able and active Premier, when he was President of the Board of Trade in 1906, inserted a clause in the Merchant Shipping Bill by which a Statutory Committee was formed to advise the Marine Department, and two of its members are representatives of this Institution on this committte. I have not heard that the Marine Department has ever asked advice from this committee on any engineering or shipbuilding question. In bringing these matters to your knowledge, I do so, with all due respect to the department, because I hope that it will some day make use of the good material it has at hand, and especially as this could be done without any additional expense. It should be a great relief to its technical officers to have the support as well as the advice in such questions of the best-informed and most-trusted men in the profession, instead of their having to bear alone and unaided the load of responsibility arising from any step that may be taken outside the conventional official routine.

SURFACE CONDENSING PLANTS.

*Notes on Surface Condensing Plants, with Special Reference to the Requirements of Large Power Stations.**

By R. J. KAULA, Member.

DURING the last few years a number of papers have been read before this and other Institutions on the subject of condensing plants. The author feels, however, that in view of the impending construction of a number of so-called super-power stations, a general survey of the subject may not be out of place. In the present paper he proposes chiefly to discuss some problems relating to the design of surface condensers and to the general arrangement and lay-out of condensing plants.

Whilst these notes are confined to plants of the surface type, it is not intended to depreciate the value of jet and ejector condensers. There have been marked improvements latterly in the design of low-level jet plants, which have enabled them to supersede the barometric type, with its cumbersome exhaust pipe lines. Apart from the question of feed-water supply, low-level jet plants are still at a disadvantage in several respects compared with surface plants. In the first place, the quantity of air carried into the condenser with the circulating water calls for a very considerable addition to the air pump capacity and power consumption. Secondly, it is rarely possible to utilise the whole of the vacuum head for raising the circulating water, and consequently the total power consumption on the circulating water side is generally higher than on a corresponding surface plant. Lastly, the shape and size are such as to call for very extensive headroom in the condenser pit. Even so, there are probably many instances, especially in medium-size plants, where surface condensers have been and are being installed and where the use of low-level jet plants would have resulted in a material saving in first cost, without this being outweighed in other directions.

In most condenser calculations it is assumed that the heat quantity to be absorbed by the cooling medium is the latent heat of the steam corresponding to the pressure of condensation.

Table I. gives the heat units rejected to the condenser per pound of steam for a few typical initial steam conditions and turbine efficiencies, on the basis of an exhaust pressure of 1 lb. absolute. It will be seen that under the more usual conditions the latent heat slightly exceeds

TABLE I.

Steam Inlet.		Turbine Efficiency, per Cent.	Heat Units Rejected, Therms.	Latent Heat, Therms.
Pressure, Lb. per Sq. In. Abs.	Superheat, Deg. F.			
300·0	250	80	1,006	1,043
200·0	200	75	1,028	1,043
150·0	100	70	1,017	1,043
150·0	100	65	1,035	1,043
14·7	0	60	1,051	1,043

the actual value to be dealt with, so that there is a corresponding margin in hand. Since, however, most constants derived from test results make no allowance for this difference, it is the more important that a correction should be introduced where the heat units exceed the latent-heat figure.

In estimating the quantity of cooling water a further slight inaccuracy is accepted, in that the specific heat of the water is taken as unity, regardless of its consistency and temperature.

On these assumptions, the quantity of cooling water required per pound of steam to be condensed is, in pounds—

$$W = \frac{H}{T_2 - T_1} \quad . \quad . \quad . \quad (1)$$

where H = latent heat in therms,

T_1 = cooling water inlet temperature in deg. F.,

and T_2 = cooling water outlet temperature in deg. F.

The difference θ_2 between T_2 and the temperature of the steam at the pressure of condensation T_0 is to a large extent a measure of the efficiency of a condenser. Whilst test results frequently show θ_2 as low as 5 deg. F., or even 4 deg. F., it is well to estimate on 8 deg. F. or 9 deg. F., so as to ensure an ample margin of cooling water under all conditions of working.

The amount of surface area to be allowed for a given duty of condensation is an ever-recurring source of discussion. On the one hand, the designer and manufacturer aim at attaining the required result with the smallest expenditure of cooling surface. On the other hand, the user wishes to ensure that his condenser contains a sufficient margin of cooling surface to enable him to maintain his intended vacuum in daily commercial use without being compelled to have recourse to incessant cleaning of tubes.

It is as well to examine the conditions determining the cooling surface of a condenser. Formula (2) below was, the author believes, first developed by Hausbrand:—

$$S = \frac{Q\,H}{T_m\,K} \quad . \quad . \quad . \quad (2)$$

where S = cooling surface in sq. ft.,

Q = quantity of steam to be condensed per hour in pounds,

* Paper read before the Institution of Electrical Engineers on Thursday, April 3, 1919.

H = latent heat at pressure of condensation in therms,

T_m = mean temperature rise in deg. F.,

$$= \frac{T_2 - T_1}{\log_e [(T_0 - T_1)/\theta_2]},$$

and K = heat-transmission coefficient in therms per sq. ft. per hour per deg. F.

Since θ_2 is usually predetermined and the remaining factors in the formula are fixed, as conditions to be attained, S may be said to vary inversely as K. Up to a comparatively late date K was taken at a figure varying from 300 to 500. But it has been proved that K for a given condenser design varies distinctly with the cooling water velocity V.

For values of V ranging from 3 ft. to 6 ft. per second, K may be taken as a function of the square root of V. For lower velocities the rate of variation is, no doubt, greater owing to the almost entire absence of turbulence, and for higher velocities the curve flattens out somewhat. If, therefore, the surface is increased to obtain a margin, this will only be fully effective provided that the water velocity is maintained.

K, and with it the effective use of the surface provided, are naturally also dependent on efficient air extraction and on features of general design, such as the ratio of length to diameter and the careful design of the steam-inlet passage, to ensure that all parts of the uppermost tube area come within the stream path. Whilst in no way wishing to disparage the value of an ample allowance in cooling surface to guard against a rapid falling off in vacuum with comparatively slight fouling of the tubes, it cannot be sufficiently emphasised that the bare measure of the tube area presents no gauge of the margin available. The degree of dryness of a tube is known to have a material effect on its heat-transmission coefficient, and it follows that in this respect the tubes nearest to the steam-inlet opening are more effective than those placed lower down, which may be assumed to be coated with a water film. In view of this known fact it was felt that a marked disproportion might exist in the work of condensation done by the upper as compared with the lower tubes. With a view to obtaining some guidance on this question, arrangements were made by Messrs. Willans and Robinson, Limited, with Mr. Bishop, of Dundee Corporation Electricity Department, in Major Richardson's absence, to carry out a series of tests on a three-flow 5,000-kw. condenser. The results are set out in Appendix I., and the mean of the readings* show a comparatively slight difference in performance between the three passes. A single series of readings such as that given, and carried out under every-day working conditions, cannot, of course, be taken as a basis of any very definite conclusions, but they seem to show that the difference in the thickness of the water film is not very marked. The more recent development of condenser design tends to reduce the drop in pressure across the tube nests to a minimum, notably by means of ample steam lanes, and this helps to provide a maximum number of tubes within what may be termed the dry zone. The provision of steam baffles in the tube space has now been entirely abandoned as being harmful rather than otherwise. On the other hand, guide vanes in the steam inlet opening are frequently introduced to assist the initial distribution of the steam.

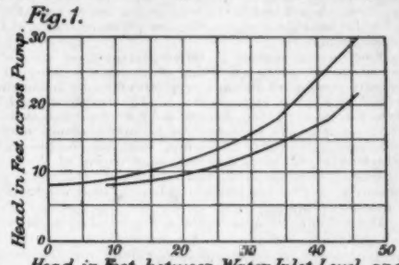
The ratio of length to diameter needs to be kept reasonably low, to avoid the formation of dead pockets at either end of the condenser, and a practical working limit for L/D may be taken at 2, whilst a value of 1·5 should be aimed at.

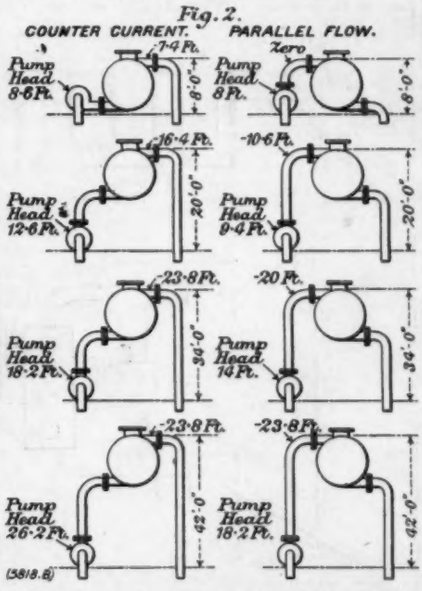
The counter-current principle is, and has been for many years, almost universally adopted in surface condenser design for land work, that is to say, the water enters the condenser at the bottom and is discharged at the top, or, in other words, the direction of the flow of the water is opposite to that of the steam. With wet-type air pumps using the condensate as sealing water this system is practically a necessity, as the condensate requires to be cooled over the lower tubes before entering the air pump. Since the majority of modern plants use dry pumps,† this point does not require the same consideration, and a higher condensate temperature obtainable with a parallel-flow condenser would be a decided advantage. On the other hand, the increased temperature of the air and vapour mixture leaving the condenser has to be counted a drawback, for reasons which are explained below.

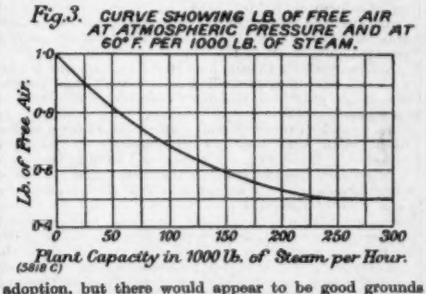
If we consider the effect of reversing the usual arrangement of the water path on the circulating-water piping immediately before and beyond the condenser, it will be found that in some instances this would facilitate design and in others the reverse would hold. It would be, no doubt, of some assistance to the designer of the lay-out not to be tied in this respect as at present.

The main object, however, in drawing attention to this question is the advantage to be derived on a syphonic circulating-water system by adopting the parallel-flow principle. In a complex pipe system, involving many bends and changes of water velocity inevitable in the circulating-water system of a condensing plant, it is not possible to rely upon maintaining the complete syphonic vacuum corresponding to the static head available for the purpose. It is reasonable to assume that the loss in vacuum is proportionately greater on a high vacuum than on a low vacuum. If we assume that the "syphonic efficiency" varies in a straight line from 100 per cent. at zero head to 70 per cent. at 34 ft. head, then the curves drawn in Fig. 1 show the total head on the circulating pump, apart from pipe friction, assuming 18 ft. condenser friction and 8 ft. between centres of water inlet and outlet branches for parallel and counter-current condensers. The difference between the two curves indicates the saving in head obtainable. It will be seen that the saving only reaches a substantial amount where the distance from water level to the highest point of the system is considerable. On the other hand, the reduction in syphonic vacuum to be maintained on a low-head system is in itself a considerable advantage. Fig. 2 shows the corresponding pressures and vacua to be maintained on a few typical heads.

It is not suggested that the parallel-flow principle possesses such advantages as to warrant its general







adoption, but there would appear to be good grounds for its use on syphonic circulating-water systems.

As far as the user is concerned, there is little to choose between cast iron and wrought steel shells. Cast iron shells are considered liable to crack when the turbine is changing from atmospheric exhaust to vacuum, and *vice versa*. On the other hand, wrought steel is liable to be subject to corrosion.

As a matter of experience, the author has not heard of a single instance where a cast iron shell has actually cracked except in the course of manufacture, but it must be admitted that it is a possibility which the station staff always view with some anxiety. Unfortunately, the railway gauge necessitates the introduction of both vertical and horizontal joints in large cast iron shells, thereby adding materially to the machining costs and to the cost and time of erection on site.

At the present time it is useless to attempt to compare the cost of shells made of the two materials as a guide to normal conditions, but it seems unlikely that cast iron will prove economical in peace time for sizes of, say, 20,000 sq. ft. and upwards.

In land practice the water velocity in the tubes varies usually between limits of 4 ft. and 7 ft. per second, depending on the permissible friction loss and the attaining of a suitable shape for the condenser. The friction loss varies with the square of the water velocity and may be divided into the following items:—

Loss in the tubes themselves	I
,, at tube inlet and outlet	II
,, in the water boxes and inlet and outlet branches	III

Whereas I is simply determined by the diameter and length of tube selected, II and III will vary according to the care exercised by designers and draughtsmen. By providing suitable bellmouths on the ferrules a saving can be obtained on II without materially adding to the cost of production. The designer is often tempted, as a convenience in the lay-out, to adopt sharp right-angle bends at the inlet and outlet branches, but these should be avoided wherever possible, especially at the inlet, as the waste in friction head may reach quite a substantial figure.

It is not proposed to describe at length the various forms of air pump now on the market, but a brief consideration of the problem of air extraction from a condenser may not be out of place. The quantity of air to be dealt with depends on the number and condition of joints under vacuum, on the air-tightness of the turbine glands, and on the quantity of air carried over with the steam. Since the peripheries of the joints and glands vary approximately as the square root of the output of the plant, the quantity of air to be allowed per pound of steam condensed should be materially less on a large unit than on a small one. The variations in air-pump capacity called for in purchasers' specifications indicate a considerable divergence of opinion as to what constitutes a reasonable allowance in this respect. It would seem very desirable that some form of standard should be established, to which all condenser makers could work, and the curve shown in Fig. 3 is put forward as a suggested basis for high-pressure turbine plants where the condenser is mounted immediately below the turbine. It is naturally important that the air pump capacity should be ample; at the same time, an excessive margin means a continuous waste of auxiliary power.

The necessary volumetric capacity of the air pump to deal with a given quantity of free air is—

$$V_0 = \frac{V_1 P_1}{P_0}$$

where V_1 = volume of air at atmospheric pressure,
P_1 = atmospheric pressure,
P_0 = partial air pressure at the air-pump suction.

Since the volume of the air varies directly as its absolute temperature, and the difference between the air inlet and outlet temperature is not likely to equal 1 per cent. of the absolute temperature, it is reasonable to neglect the question of air temperature as affecting its volume at a given pressure.

According to Dalton's Law, the total pressure P_v, i.e., the pressure corresponding to the vacuum to be maintained, is the sum of the vapour pressure P_s and the partial air pressure. Hence $P_a = P_v - P_s$. Assuming the air to leave the condenser in a saturated condition, then P_s is the pressure of dry saturated steam at the temperature of the mixture, and it follows that P_a, and with it V_a, depend materially on the temperature of the mixture in the condition in which it enters the pump.

In a wet-air pump the mixture is in immediate contact with the sealing water, and its temperature is reduced to approximately that of the latter. In rotary air pumps it is generally assumed that the mixture in coming into contact with the water jet assumes the temperature of the jet, that is to say, that the air pump fulfils the function of an air cooler before and in addition to acting as a pump. It seems doubtful whether the cooling is carried out without impairing the primary function of the pump, and a number of designers prefer to cool the mixture by passing it over a batch of tubes taking their supply of water from the circulating water inlet. In a parallel-flow condenser the temperature of the mixture would naturally be higher than in a counter-current condenser, and this precaution would therefore be all the more necessary.

Modern types of air pumps can be divided under three headings:—

1. Reciprocating pumps.
2. Rotary air pumps.
3. Steam ejector pumps.

The Edwards pump is the only example of the first group which can still claim to hold its own even in the largest installations, but where vacua of over 27½ in. to 28 in. are concerned it may be ruled out, except in conjunction with a vacuum augmentor. Its comparatively low power consumption, reliability and low maintenance cost are its chief advantages. Where a vacuum augmentor is in use the steam consumed by the jet requires to be added to the pump power consumption, and in practice this amounts to anything from 0·5 to 1 per cent. of the main turbine consumption, whereas the pump itself should not consume more than about 0·2 per cent. of the turbine power. The disadvantages of the Edwards pump are its bulk and its low running speed, and where the pump uses the condensate as sealing water the temperature of the latter needs to be kept low, and the condensate becomes strongly aerated—a frequent source of boiler troubles.

All rotary types of air pump consist of one or more water jets, which entrain and compress the air. In the case of the kinetic system the water jet works in series with a steam jet. The characteristic of the earlier designs was such as to show very little difference in

* [The demands upon our space will not permit us to print this Appendix.—Ed.]

† The terms "wet" and "dry" air pumps are here used in accordance with common practice, to differentiate between pumps extracting the condensate as well as the air and those dealing with the air only. Where the latter form of pump consists of nothing more than a water jet, the use of the adjective "dry" is, of course, paradoxical.

capacity between high and low vacua, with the result that the time taken to evacuate was excessive, and anything in the nature of a heavy air leak caused a sharp fall in vacuum. These disabilities have been overcome in later designs, but the efficiency of such pumps is still very low, and it is reasonable to expect a marked improvement in this respect as designs develop.

The steam ejector type of air pump represents a development of the Parsons vacuum augmentor. In their simplicity they equal the water-jet type, with the advantage of using pipes of small dimensions instead of comparatively heavy water pipes. In the matter of power consumption it is claimed that although the quantity of steam consumed is appreciable, practically the whole of the heat value is returned to the feed water, so that the actual loss of heat is well below that of any other system. This claim requires some qualification, as, in the first place, a similar result can be obtained by driving a rotary pump with a back-pressure turbine exhausting into a feed heater, and, secondly, with the condensate temperature within a few degrees of vacuum temperature, and efficient economisers in use, the number of heat units which the feed water can absorb in this manner economically is limited. However, there can be little doubt that the claims of the steam ejector are strong enough to ensure its success and widespread application.

The failure of an air pump does not in itself involve an immediate change to atmosphere, as the consequent accumulation of air in the condenser is very gradual where the system is reasonably airtight. Provision should therefore be made, where necessary, by means of suitable non-return valves, to ensure that such a failure is not accompanied by an inrush of air through the air pump.

The introduction of rotary air pumps brought in its train the general use of separate condensate pumps. The conditions to be met are such as to impose the utmost difficulty on the design of a pump of the centrifugal type. It is not, therefore, surprising that a good number of failures required to be overcome, and much practical experience had to be gained before satisfactory designs were evolved. It is now appreciated that low water velocities on the suction side are essential, as well as in the impeller, to guard against cavitation troubles. To ensure these conditions, and stability over the large range of fluctuating loads which such pumps are called upon to handle, it is well to work on the lower or flat part of the pump characteristic, that is to say, well below the point of maximum efficiency. Since the total power involved is small, the question of efficiency is not of material consequence.

An ample static head on the suction side is required to overcome pipe friction and to ensure that the water enters the pump with a sufficient initial velocity. The connecting pipes between the condenser and the pump should be as short as the lay-out will permit, with a minimum number of joints. Unfortunately, the same reasons for inserting non-return valves on the suction side apply to condensate as to air pumps.

The circulating pump forms a vital link in the chain of apparatus that constitutes a condensing plant, as regards continuity of running, since its failure for however short a period means an immediate and complete failure of the vacuum.

Reliability is therefore naturally a first consideration. At the same time the power consumption is comparatively high, so that a high efficiency needs also to be looked for.

The material of the shaft and impeller require, of course, to be selected to suit the nature of the water.

Since all but the smallest circulating pumps are of the double impeller type, balancers are not usually needed. It is, however, advisable to avoid pipe bends in the horizontal plane in close proximity to the suction inlet, as they are apt to produce an uneven distribution of the water over the two halves of the impeller and to throw the pump out of balance. Even when the water levels are constant provision should be made for reasonable variations in head, as it is not possible to predetermine the friction heads within a few per cent., and they are in any case dependent on the condition of the pipes and condenser tubes.

The characteristics of the pump should be adapted to that of its prime mover, and when this latter permits of speed regulation the pump should be able to take full advantage of this feature without loss of efficiency. It is then possible to regulate the water supply according to the head, by varying the pump speed, and this method is much to be preferred to throttling.

In large power stations it is customary to provide separate turbo-generating units for supplying the power to all auxiliary machinery and for lighting purposes, so as to ensure complete independence of the main plant.

Now that there is no difficulty in obtaining gearing for driving the generators, there is nothing to choose in the matter of first cost or economy between three-phase and direct-current supply for this purpose.

The possibility of obtaining speed variation is a marked advantage in favour of the latter system, and this applies particularly to the circulating pumps.

In smaller stations, where the total power consumption of the auxiliary machinery is hardly sufficient to warrant the provision of such auxiliary units, the necessity of starting up on atmosphere after a complete shut down, where electric motors are used for driving the condenser pumps, has led to the extensive adoption of steam-turbine driven pumps.

Since the power consumption of the condensate pumps is too small for a separate turbine drive, a steam drive can only be arranged by coupling this pump to the air pump or by coupling the three pumps to a single turbine. Such an arrangement, however, has considerable drawbacks. In the first place, the normal speeds of the pumps have no relation to one another, and if the circulating-pump speed is forced up to suit that of the condensate pump, this involves excessively long shafts and small clearances.

Then, again, the pipe connections are very difficult to arrange, and the placing in line of so many shafts gives every opportunity for the appearance of resonant vibrations.

Under the circumstances it seems preferable to drive the condensate pump electrically, particularly since the plant can be started on vacuum with this pump standing. The condensate will accumulate in the bottom of the condenser until it is forced over into the air pump.

If the steam consumed by the combined air and circulating pumps is excessive for feed-heating purposes, as, in fact, is usually the case, it becomes necessary to provide separate drives for the two pumps, or to build the auxiliary turbine of the pass-out type. Such steam as cannot be utilised in the feed heater can either exhaust into the condenser or into the low-pressure stages of the main turbine.

The former system is rather extravagant in steam consumption, although where gear drive is adopted it is quite possible to obtain a very fair efficiency in turbines of 200 to 300 h.p. and upwards. If the auxiliary turbine exhausts into the low-pressure stage of the main turbine the economy will be found to be about equal to that obtained with electric driving, but the complications which this introduces into the construction of the main turbine are undesirable, and additional steam space is required in the low-pressure blading just where it is hardest to obtain.

Apart from the absence of speed regulation, already referred to, an induction motor drive off the main supply is not to be recommended, especially on fluctuating loads, in that a rush of load means a fall in frequency, and consequently of the pump speed, at a time when the pumps should be working at their maximum capacity.

Fig. 4.

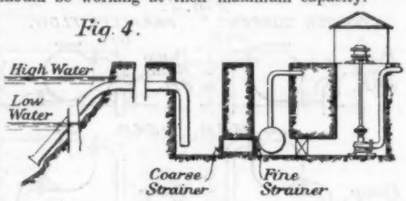
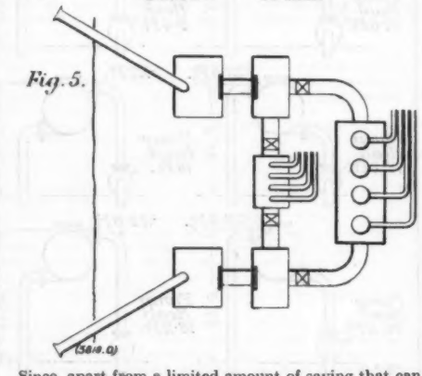


Fig. 5.



Since, apart from a limited amount of saving that can be obtained at lighter loads by speed regulation or throttling, the power consumed by the condenser auxiliaries represents a constant loss, their most economical arrangement deserves the closest attention.

So many factors enter into the question, which vary with the conditions prevailing in each individual station, that it has only been possible to consider the subject on very general lines.

In a modern power station, where the water quantity to be dealt with amounts to hundreds of thousands of gallons per minute, the means of handling the water is a primary consideration in the design and lay-out of the engine-house. If we consider first the simplest case of a non-tidal riverside station, where the river level coincides with the condenser basement level, in such a case the most satisfactory plan is to allow the water to flow by gravity in an open concrete duct into the engine-room, with branches leading from the main duct to each pump, the latter being placed close to the condensers. The discharge pipes from the condensers should be led into a corresponding outlet duct, in which the water is maintained at a sufficient level to enable it to return to the river by gravity. A similar arrangement can be adopted in a cooling tower station if separate pumping plant is provided alongside the towers to deliver the water to the top of the towers. This arrangement of separate pumps has much to be said in its favour in any case, as it makes it possible to adjust the number of towers in use according to the atmospheric conditions and independently of the number of condensers on load. Where the water-level conditions prohibit the use of open ducts, it is preferable in large stations to run separate pipe lines for each unit.

Perhaps the most difficult condition to be dealt with is that of a tidal river containing large quantities of solid matter, which require to be strained before the water enters the condenser. Fig. 4 shows a diagrammatic arrangement of strainers and pumps to deal with such conditions. The water is syphoned from the river into a strainer chamber, and passes from there through two sets of grid strainers into a clean-water chamber, and then to the pump house. The strainer chamber and clean-water chamber are duplicated, so that the flow of water may be reversed for the purpose of clearing the strainers and at the same time to prevent silting of the main pipe inlets. The discharge pipes from the condensers are led into a discharge chamber, their outlets being below water level. Valves are shown between the clean-water chambers and the pump house, and discharge chamber to give the required reversal of flow. Such an arrangement is naturally high in first cost, but this would be fully warranted in the case of a large power station under the conditions named. In smaller plants and where no great difference in water levels has to be dealt with, strainers of the endless-chain type, with water jet cleaning gear, as first introduced by Messrs. Dickinson and Porter at Leeds, are generally effective. So called revolving strainers, such as the Baillie and Jackson type, are too cumbersome for large plants, and the inevitable leakage loss is a considerable drawback to their use.

This question of straining the circulating water is nearly always one requiring much consideration in the case of riverside stations, and should be taken account of in making comparisons with cooling-tower propositions.

Where towers are in use it will usually be found to pay to soften the make-up water if the latter is at all hard, but such a process would be prohibitive in cost if applied to the whole bulk of the cooling water. This apparent advantage of cooling towers is partly offset by the fact that softening is more important where they are used owing to the higher cooling water temperature in the condenser tubes. When the formation of scale cannot be avoided, the brushing out of tubes is rarely completely effective, and the only remedy is boiling out with hydrochloric acid.

It follows from formulæ (1) and (2) that as the difference between vacuum temperature T_1 decreases, so the rate of increase of cooling water quantity and surface to be allowed rises. Since it is customary in modern practice to work on a rapidly-rising part of the resultant curves, a very substantial reduction in water quantity and surface will show a comparatively moderate reduction in vacuum. Thus a condenser designed for a vacuum of 28½ in. (Bar. 30 in.), with cooling water at 70 deg. F., will still be capable of maintaining a vacuum of 27 in. (Bar. 30 in.), if the cooling water quantity and surface are halved, and when dealing with the same quantity of steam. If, therefore, a condensing plant is arranged to consist of two condenser bodies with separate water connections and valves, it is possible to open up the water side of one condenser at a time for cleaning purposes, and to continue running at approximately full load without a heavy loss of vacuum. It is, of course, not possible to remove tubes under such conditions, as the inactive condenser remains under vacuum. Naturally, such an arrangement means a substantial increase in first cost, greatly complicates the general lay-out of the whole plant, and can only be justified where the water conditions are exceedingly poor.

Several makers have introduced condenser designs in which the same result is obtained in a single condenser by splitting the waterways and doors. Such designs overcome the primary difficulties of the lay-out, but the complications of pipe work and valves are not in any way reduced.

A special committee is now investigating the problem of tube erosion, and their report, when available, will no doubt mark a substantial advance in the process of solving this question. In the meantime it may suffice to say that no individual metal or alloy has proved immune in all cases. Protection devices, such as the Harris Anderson and Cumberland, have been very helpful in many instances that have come under the author's notice.

In conclusion, the author regrets that it has not been possible to embody further test results in the present notes, but it is at all times difficult to obtain reliable condenser figures under working conditions, and under war conditions it has been found impracticable to do so.

RUBBER AS A COLLOID.—In a paper read before the Birmingham Section of the Society of Chemical Industry last December, Dr. D. F. Twiss summed up the varied reasons for regarding rubber as a colloid, and as an emulsoid rather than as a suspensoid. The difference between the two classes is that the particles of the suspensoid are solid, whilst those of emulsoids are themselves fluid and to a certain extent soluble in the dispersion medium. Rubber first makes its appearance in a doubly-colloidal condition, in fact. The latter contains minute globules, from 0·5 μ to 2 μ in diameter in hevea brasiliensis, suspended in an aqueous serum and in distinct Brownean movement; other rubbers contain smaller particles; in electric fields the particles travel towards the anode. These particles are probably rubber itself; the second colloid in the latter is protein matter. Like all emulsoids rubber has strong adsorptive properties; with Höhn and Ostwald, Twiss doubts that the rubber vulcanisation by sulphur really amounts to a chemical combination in the strict sense; adsorption certainly plays a noteworthy part in the vulcanisation. Rubber is also a solvent for gases; hydrogen will diffuse much more rapidly through a fine aperture of an indifferent substance than the heavier carbon dioxide would do, but carbon dioxide will diffuse more rapidly through a septum of rubber than hydrogen, because this latter process is an adsorption rather than a diffusion. The colloidal nature of natural rubber, Dr. Twiss pointed out, is probably also one of the main difficulties of the preparation of synthetic rubber.